EPC

100 Series (1xx)

User Manual

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Table of Contents

1 Introduction **4**
2 Basic System Overview **4**
3 General Instructions **5**
3.1 Password Protection 5
3.2 PC Interface Groupings 5
4 Module Configuration **6**
4.1 General Configuration 6
4.1.1 Password Protection (000) 6
4.1.2 Operating Modes (200) 6
4.1.2.1 Dynamic Function Selection with Fault Monitor 7
4.1.2.2 Dynamic Function Selection with Watchdog Monitor 7
4.1.2.3 Static Function Selection with Watchdog Daisy Chain 7
4.1.2.4 Dynamic Function Selection with Limit Monitor 8
4.1.2.5 Static Function Selection with Fault Monitor 8
4.1.2.6 Static Function Selection with Watchdog Monitor 8
4.1.2.7 Static Function Selection with Watchdog Daisy Chain 9
4.1.2.8 Static Function Selection with Limit Monitor 9
4.1.3 Program Block Configuration (21x) 10
4.1.4 EPC Hardware and Software Information 11
4.1.5 Serial Communication 12
4.1.6 Update Rate 12
4.2 Program Configuration 12
4.2.1 Overview 12
4.2.2 PI Control Algorithms 12
4.2.3 Pressure Control Programs (40x, 41x) 13
4.2.4 Flow with Pressure Limit Programs - Generation 2 (42x, 43x) 15
4.2.5 Load Sense Control Programs (44x, 45x) 18
4.2.6 Simple Flow Control Programs (46x, 47x) 21
4.2.7 Pressure Control with Flow Preset Programs - Generation 2 (48x, 49x) 22
4.2.8 Advanced Control with Feed-Forward Programs - (50x, 51x) 26
4.3 Pump Controller Configuration 30
4.3.1 Overview 30
4.3.2 Configuration 30
4.3.2.1 Function Zero Stroke Command 31
4.3.2.2 Stroke Controller 31
4.3.2.3 HP Limiter 32
4.3.2.4 Output Polarity 32
4.3.2.5 Output Current Limit 33
4.3.2.6 Dither 33

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4.3.3 Configuration Example 34
4.4 Analog IO Configuration 35
4.4.1 General Purpose Analog Input Configuration 35
4.4.2 LVDT Fine-Adjustable Analog Input Configuration 38
4.4.3 Programmable Analog Outputs 39
4.4.4 Servo Valve Driver with Stroke Feedback 40
4.4.4.1 Servo Attenuation and Offset 40
4.4.4.2 Stroke Feedback Device 41
4.4.4.3 Adjustment Mode 41
4.4.5 LVDT Adjustment Algorithm 43
4.4.5.1. Determining LVDT Configuration Range 43
4.4.5.2 Adjustment Algorithm 44
4.5 Advanced Configuration 46
4.5.1 Horsepower Limit Factor Calculation 46
4.5.1.1 Experimental HP Limit Factor 47
4.5.1.2 Theoretical HP Limit Factor 48
4.5.2 Ramp Configuration 50
5 Module Diagnostics 53
5.1 Diagnostic Representation of Numbers 53
5.1.1 DAC Counts 53
5.1.2 Voltage and Percentages 53
5.2 Basic Diagnostics on Front Panel 53
5.2.1 Run / Fault LED 54
5.2.2 Valve Current LED 54
5.2.3 Feedback LED 54
5.2.4 Testpoint 54
5.3 Basic Diagnostics with PC Interface 55
5.4 Programmable Outputs Diagnostic 56
5.5 Advanced Diagnostics 56
5.5.1 Module Faults 56
5.5.2 System Messages 57
6 Technical Data 58
6.1 Module Pinout 58
6.2 Sample Connection Diagram 59
6.3 Specifications 60
6.4 IO Summary 60
6.5 Cable Recommendations and Terminal Information 60
7 Technical Support 61
8 Ordering Information 62
9 Appendix 65
9.1 Appendix A Generation 1 Control 65
9.1.1 Flow with Pressure Limit Programs (42x, 43x) 65
9.1.2 Advanced Flow with Pressure Limit Programs (48x, 49x) 68

1 Introduction

The EPC is a fully programmable microcontroller-operated controller and amplifier for servo controlled hydraulic pumps and valves. The unit can be configured for several types of control applications including:

- Flow Control
- Pressure Control or Load Control
- Flow Control with Pressure Limit (PQ-Control)
- Horsepower Control (Pump Stroke and Pressure)
- Pressure Control with Flow Preset
- Advanced Control with Feed-Forward

Figure 1: EPC Module

2 Basic System Overview

The EPC allows one (1) single control axis with a power amplifier to drive VS-, VV- and VM-controlled pumps and valves. The basic pump controller configuration allows for fast (up to a 1600Hz) closed loop response with both stroke position and pressure feedback. In addition, two (2) independent function programs can be dynamically selected with a digital input signal. The unit provides a digital output for simple diagnostics or a watchdog signal.

Three (3) general-purpose analog inputs are provided for command and pressure feedback signals including ±10 VDC, 0-to-20 mA, or 4-to-20 mA (see Section 6.4 Note 3 for current mode resister). Additionally, one (1) analog input is provided as a dedicated fine-adjustable LVDT stroke feedback device. The module allows for (2) two low-power programmable output signals.

The device is configured by first assigning one of twelve (12) built-in function programs to each of the two (2) program blocks. Typically, the output of the function programs is then passed to the Pump Controller, which provides the valve command.

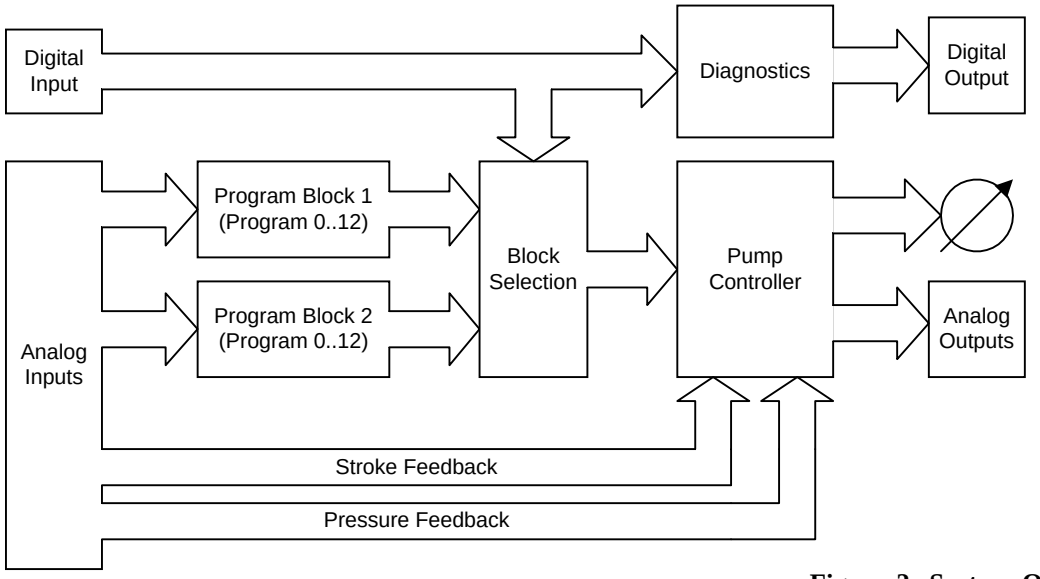

Figure 2: System Overview

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If the full features of the module are used, up to three (3) independent closed loop PI (Proportional with Integral) control algorithms are utilized. Most function programs provide a closed loop control algorithm for pressure or stroke, while the Pump Controller can be configured for both stroke and power feedback.

The module is programmable through the PC Interface software. Various Forms in the software will be discussed throughout the manual. Programming items are located in these Forms.

3 General Instructions

3.1 Password Protection

The EPC allows for edit protection of all programmable parameters. Please refer to Section 4.1.1 for a thorough discussion of Password Protection.

3.2 PC Interface Groupings

The PC interface provides a programming and monitoring interface. A toolbar menu loosely groups functions into Forms in the following manner:

File	File, Print, and Communication Commands
General	Password and Communication Setup, Program Selection and Mode Selection (program items 000 and 2xx)
Program	Program Configuration (program items 4xx and 5xx)
Pump Controller	Pump Controller Configuration (program items 8xx)
Diagnostics Analog IO Configuration	General Purpose Input Configuration, Fine-Adjustable Input Configuration (LVDT), Diagnostics, Servo Driver Configuration, Programmable Output Selections (program items 84x, 85x, 86x, 88x, and 93x)
Diagnostics Advanced Configuration	Ramp Configuration and Advanced HP Limit Setup (program items 87x and 810)
Language	Select English, German or Italian
Help	User Help

Items are programmable either through Numeric Input boxes or Drop-Down List boxes.

4 Module Configuration

4.1 General Configuration

General Configuration parameters include Password, Mode, and Communication Setup Parameters.

4.1.1 Password Protection (000)

Program Item	Range	Description
000	0 to 255	Password

Table 1: Password Protection

The EPC has a simple lockout password that can be used to protect the program configuration from accidental changes. The password is entered through program item 000 in the General Configuration Form.

If the password is set to 249, the user will be able to modify any editable entry. Any other password will place the device in read-only mode. The user will not be able to modify any entry in this mode.

4.1.2 Operating Modes (200)

Program Item	Range	Description
200	0 to 7	Operating Mode: 0: Dynamic Function Selection with Fault Monitor 1: Dynamic Function Selection with Watchdog Monitor 2: Static Function Selection with Watchdog Daisy Chain 3: Dynamic Function Selection with Limit Monitor 4: Static Function Selection with Fault Monitor 5: Static Function Selection with Watchdog Monitor 6: Static Function Selection with Watchdog Daisy Chain 7: Static Function Selection with Limit Monitor

Table 2: Operating Modes

The EPC has eight (8) operating modes. For Dynamic Modes, the EPC will dynamically select the active function program based on the state of the digital input and the Program Block settings. For Static Modes, the EPC has only function block 1 active and the digital input may be used for an alternative purpose defined by that particular mode described in the following sections.

The digital output is always controlled by the mode specification.

Note: Firmware versions prior to 1.10 only support Modes 0, 1 and 2.

4.1.2.1 Dynamic Function Selection with Fault Monitor

This operating mode is selected by setting program item 200 to 0 by choosing Mode 0: Dynamic Function Selection with Fault Monitor from the General Configuration Form.

In this operating mode, the digital input selects which program block is active. If the digital input is low (<5 VDC), Program Block 1 is made active and the program defined in program item 210 is used. If the digital input is high (> 5VDC), Program Block 2 is made active and the program defined in program item 211 is used. Refer to Section 4.1.3 for discussion of Program Block Configuration (21x).

The digital output provides standard condition status. If no faults are present, the digital output will be high (Vsupply); If faults are present, the digital output will be low (0 VDC). Refer to Section 5.5 for information on module fault and message conditions.

4.1.2.2 Dynamic Function Selection with Watchdog Monitor

This operating mode is selected by setting program item 200 to 1 by choosing Mode 1: Dynamic Function Selection with Watchdog Monitor from the General Configuration Form of the PC Interface.

In this operating mode, the digital input selects which program block is active. If the digital input is low (<5 VDC), Program Block 1 is made active and the program defined in program item 210 is used. If the digital input is high (> 5VDC), Program Block 2 is made active and the program defined in program item 211 is used. Refer to Section 4.1.3 for discussion of Program Block Configuration (21x).

The digital output provides a watchdog signal of approximately 100 Hz.

4.1.2.3 Static Function Selection with Watchdog Daisy Chain

This operating mode is selected by setting program item 200 to 2 by choosing Mode 2: Static Function Selection with Watchdog Daisy Chain from the General Configuration Form.

In this operating mode, Program Block 1 is always active and the program defined in program item 210 is used. Program Block 2 is always inactive and program item 211 has no function. Refer to Section 4.1.3 for discussion of Program Block Configuration (21x).

The digital input is passed through the module into the digital output. In this way, one single watchdog timer can be used for a number of EPC modules. One EPC module would need to be configured for Mode 1: Dynamic Function Selection with Watchdog Monitor; the remaining EPCs would be configured for Mode 2. Any module failure would break the daisy chain.

4.1.2.4 Dynamic Function Selection with Limit Monitor

This operating mode is selected by setting program item 200 to 3 by choosing Mode 3: Dynamic Function Selection with Limit Monitor from the General Configuration Form.

In this operating mode, the digital input selects which program block is active. If the digital input is low (<5 VDC), Program Block 1 is made active and the program defined in program item 210 is used. If the digital input is high (> 5VDC), Program Block 2 is made active and the program defined in program item 211 is used. Refer to Section 4.1.3 for discussion of Program Block Configuration (21x).

The digital output provides a signal as to whether the stroke command is being limited due to an over-Power or over-Pressure condition. The over-Power condition is specified from the Horsepower Limiter. The only supported over-Pressure condition is specified by the Flow with Pressure Limit Control algorithm (Generation 2).

If either limiting condition is taking place, the digital output will be low (0 VDC). If no limiting situation is taking place, the digital output will be high (Vsupply). If the Horsepower limiter is disabled and a program other than a Flow with Pressure Limit Control program (Generation 2) is active, the digital output will be high.

4.1.2.5 Static Function Selection with Fault Monitor

This operating mode is selected by setting program item 200 to 4 by choosing Mode 4: Static Function Selection with Fault Monitor from the General Configuration Form of the PC Interface.

In this operating mode, Program Block 1 is always active and the program defined in menu 210 is used. Program Block 2 is always inactive and menu item 211 has no function.

The digital output provides standard condition status. If no faults are present, the digital output will be high (Vsupply); If faults are present, the digital output will be low (0 VDC).

4.1.2.6 Static Function Selection with Watchdog Monitor

This operating mode is selected by setting menu item 200 to 5, or by choosing Mode 5: Static Function Selection with Watchdog Monitor from the General Configuration form of the PC Interface.

In this operating mode, Program Block 1 is always active and the program defined in menu 210 is used. Program Block 2 is always inactive and menu item 211 has no function.

The digital output provides a watchdog signal of approximately 100 Hz.

4.1.2.7 Static Function Selection with Watchdog Daisy Chain

This operating mode is selected by setting menu item 200 to 6 by choosing Mode 6: Static Function Selection with Watchdog Daisy Chain from the General Configuration form of the PC Interface.

In this operating mode, Program Block 1 is always active and the program defined in menu 210 is used. Program Block 2 is always inactive and menu item 211 has no function.

The digital input is passed through the module into the digital output. In this way, one single watchdog timer can be used for a number of EPC modules. One EPC module would need to be configured for Mode 1 (Dynamic Function Selection with Watchdog Monitor) while the remaining EPCs would be configured for Mode 2. Any module failure would break the daisy chain.

4.1.2.8 Static Function Selection with Limit Monitor

This operating mode is selected by setting menu item 200 to 7, by choosing Mode 7: Static Function Selection with Limit Monitor from the General Configuration form of the PC Interface.

In this operating mode, Program Block 1 is always active and the program defined in menu 210 is used. Program Block 2 is always inactive and menu item 211 has no function.

The digital output provides a signal as to whether the stroke command is being limited due to an over-Power or over-Pressure condition. The over-Power condition is specified from the Horsepower Limiter. The only supported over-Pressure condition is specified by the Flow with Pressure Limit Control algorithm (Generation 2).

If either limiting condition is taking place, the digital output will be low (0 VDC). If no limiting situation is taking place, the digital output will be high (Vsupply). If the Horsepower limiter is disabled and a program other than a Flow with Pressure Limit Control program (Generation 2) is active, the digital output will be high.

4.1.3 Program Block Configuration (21x)

Program Item	Range	Description
210	0 to 12	Program Selection for Program Block 1
		0: No Program used for Block 1 *(refer to Section 4.3.2.1)*
		1-12: Program 1 to 12 used for Block 1
211	0 to 12	Program Selection for Program Block 2
		0: No Program used for Block 2 *(refer to Section 4.3.2.1)*
	1 to 12:	Program 1 to 12 used for Block 2

Table 3: Program Block Configuration

The program block configuration parameters are used in conjunction with the module operating modes to assign pre-defined programs to the two (2) program blocks.

Dynamic Operating Modes: These modes are referred to as “dynamic” because the digital input selects which Program Block is active. If the digital input is low (<5 VDC), Program Block 1 is made active and the program defined in menu 210 is used. If the digital input is high (> 5VDC), Program Block 2 is made active and the program defined in menu 211 is used (see Example).

Static Operating Modes: These modes are referred to as “static” because Program Block 1 is always active and menu 210 defines the active function program. Menu 211 has no function in operating mode 2. The static operating modes also free the digital input to be used for a function other than program selection.

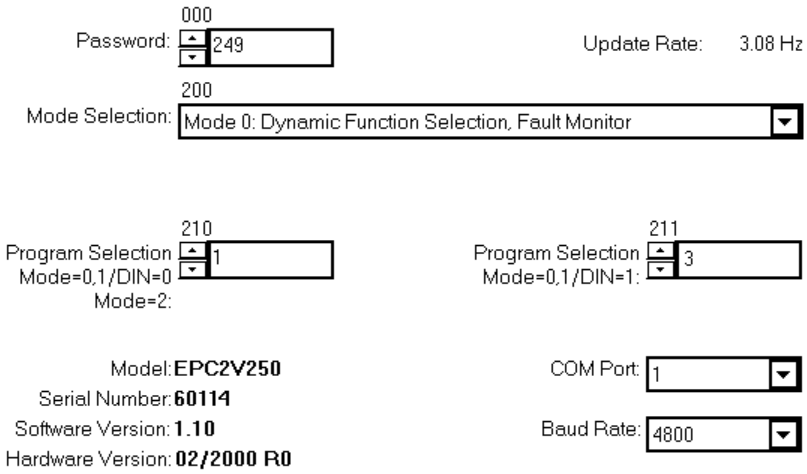

Figure 3: General Configuration Form

Example 1: Operating Mode (program item 200) is set to 0 (Dynamic Function Selection with Fault Monitor). Program Selection for Program Block 1 (program item 210) is set to 1 (Pressure Control) and Program Selection for Program Block 2 (program item 211) is set to 3 (Flow with Pressure Limit Control). See Figure 3.

If the digital input is low (<5 VDC), Program Block 1 is made active and the active program is Program 1 (Pressure Control). If the digital input is high (> 5VDC), Program Block 2 is made active and the active program is Program 3 (Flow with Pressure Limit Control).

Example 2: Again, operating Mode is set to 0. Program Selection for Program Block 1 (program item 210) is set to 1 (Pressure Control) and Program Selection for Program Block 2 (program item 211) is set to 0 (No Program).

If the digital input is low (<5 VDC), Program Block 1 is made active and the active program is Program 1 (Pressure Control). If the digital input is high (> 5VDC), Program Block 2 is made active, but since no program is activated, the module uses a special zero function command to command the pump controller (refer to Section 4.3.2.1 for configuration of the Function Zero Stroke Command).

Mode 2: For operating mode 2 (Static Function Selection with Watchdog Daisy Chain) the digital input is used as a watchdog input signal. Therefore, no dynamic function selection is possible. In this mode, Program Block 1 is always active and program item 210 defines the active function program. Program item 211 has no function in operating mode 2.

The program blocks are selected from the General Configuration Form.

4.1.4 EPC Hardware and Software Information

After an upload from the EPC to a PC, several non-editable parameters are shown in the General Configuration Form. These items include the model, serial number, software version and hardware version. See Figure 3.

4.1.5 Serial Communication

The PC software interface must be configured properly to communicate to the EPC module. The COM Port setting should match the physical connection on the PC. The Baud Rate setting should be set to 4800 Baud. The COM port number and baud rate is listed on the General Configuration Form. See Figure 3.

4.1.6 Update Rate

The PC interface will update on-line information as quickly as possible. Often times this can be improved by limiting the number of Windows™ applications. Typically, the EPC update rate will be maximized in the 2 to 3 Hz range. See Figure 3.

4.2 Program Configuration

4.2.1 Overview

The EPC offers 12 pre-defined programs. The programs range from simple flow control to advanced functionality. Six different types of programs exist, and the module provides two distinct copies of each program.

Programs 1 and 2 provide Pressure Control programs. Programs 3 and 4 provide Flow with Pressure Limit Control programs. Programs 5 and 6 provide Load Sense Control programs. Programs 7 and 8 provide Simple Flow Control programs. Programs 9 and 10 provide Pressure Control with Flow Preset programs. Finally, Programs 11 and 12 provide Advanced Control with Feed-Forward.

Programs 3, 4, 9, and 10 have been modified since the manual 2 revisions ago (Bulletin 83260A) to improve performance. This software enhancement is called Generation 2. It requires EPC software versions 1.07 or later and PC Interface software version 1.02.0004 or later. See Appendix A for Generation 1 information.

Programs 11 and 12 have been added since the last manual (Bulletin 83260B) as an added feature. It requires EPC software versions 1.10 or later and PC Interface software version 1.20 or later.

Under usual circumstances, the pre-defined programs are used as outer loop control. The output of the pre-defined programs is normally passed through to the Pump Controller module (refer to Section 4.3.1 for an overview of the Pump Controller).

4.2.2 PI Control Algorithms

Most programs use a PI (Proportional with Integral) control scheme. Although an advanced tutorial on digital control systems is beyond the scope of this technical document some level of knowledge and experience is necessary to successfully implement the control programs.

The basis of a PI controller is that an output signal is produced due to a difference between a command and feedback term (the difference is usually referred to as *Error*). The output signal for a PI control is made of a proportional error signal combined with an integral error signal.

4.2.3 Pressure Control Programs (40x, 41x)

Program Item	Range	Description
400	1 to 100	Program 1: Pressure Command Preset
401	0 to 5	Program 1: Pressure Command Source
402	1 to 5	Program 1: Pressure Feedback Source
403	0 to 1	Program 1: Program Output Destination
404	0 to 100	Program 1: KP
405	0 to 100	Program 1: KI
410	1 to 100	Program 2: Pressure Command Preset
411	0 to 5	Program 2: Pressure Command Source
412	1 to 5	Program 2: Pressure Feedback Source
413	0 to 1	Program 2: Program Output Destination
414	0 to 100	Program 2: KP
415	0 to 100	Program 2: KI

Table 4: Pressure Control Programs Configuration

Function Programs 1 and 2 provide for basic Pressure Control. Program 1 is configured in program items 400 through 405 or from the Program 1 Form. Program 2 is configured in program items 410 through 415 from the Program 2 Form.

Pressure Command Preset: The Pressure Command Preset allows for direct numeric input for the control program. The preset is configured as a percentage, with 0% being equivalent to a 0VDC input signal and 100% being equivalent to a +10VDC signal.

Pressure Command Source: The Pressure Command Source selects the source of the pressure command for the program. Valid entries are (0) Preset Value, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If the Preset Value is chosen, the Pressure Command Preset is used as the program command.

Pressure Feedback Source: The Pressure Feedback Source selects the source of the pressure feedback for the program. Valid entries are (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1.

Program Output Destination: The Program Output Destination selects the output of the program. Valid entries are (0) Pump Controller or (1) Direct. If the Pump Controller is chosen, the output of the Program will be the input to the Pump Controller module. If Direct is chosen, the output of the Program will by-pass the Pump Controller module and is passed directly to the servo driver. Under most circumstances, the Pump Controller should be chosen as the output destination.

KP and **KI**: KP and KI provide the proportional and integral constants, respectively, for the PI control algorithm. Both terms are expressed as 0 to 100% of a maximum value. The PI control loop can be made a P-only control loop by setting the KI term to 0. Likewise, the PI control loop can be made an I-only control loop by setting the KP term to 0.

Program Overview: The Pressure Control Program is a straightforward PI control algorithm. Comparing the command to the feedback value produces an error value. The error is multiplied by the KP and KI constants to produce the Yp and Yi contributions to the program output.

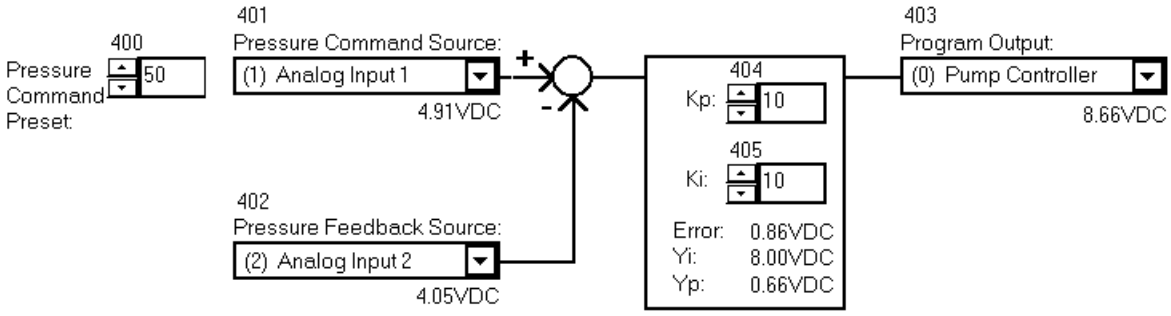

Figure 4: Pressure Control Program

Example: Figure 4 shows the Program 1 Form for Pressure Control. The Pressure Command Source is Analog Input 1 (program item 401=1) and the Pressure Feedback Source is Analog Input 2 (program item 402=2). The Pressure Command Preset has a value of 50% (program item 400=50) although it is not used for this particular example.

The error signal is produced by comparing the command to the feedback signals: 4.91V - 4.05V = 0.86V. The Yi and Yp signals are produced from the PI controller and the program output is roughly equal to their sum: 8.00V + 0.66V = 8.66V. The Program Output is set to the Pump Controller (program item 403=0).

4.2.4 Flow with Pressure Limit Programs - Generation 2 (42x, 43x)

Program Item	Range	Description
420	0 to 100	Program 3: Flow Command Preset
421	1 to 100	Program 3: Pressure Limit Preset
422	0 to 5	Program 3: Flow Command Source
423	0 to 5	Program 3: Pressure Limit Source
424	1 to 5	Program 3: Pressure Feedback Source
425	0 to 1	Program 3: Program Output Destination
426	0 to 100	Program 3: KP
427	0 to 100	Program 3: Full Scale Command
428	0 to 100	Program 3: Pressure Breakpoint Preset
429	0 to 7	Program 3: Pressure Breakpoint Source
430	0 to 100	Program 4: Flow Command Preset
431	1 to 100	Program 4: Pressure Limit Preset
432	0 to 5	Program 4: Flow Command Source
433	0 to 5	Program 4: Pressure Limit Source
434	1 to 5	Program 4: Pressure Feedback Source
435	0 to 1	Program 4: Program Output Destination
436	0 to 100	Program 4: KP
437	0 to 100	Program 4: Full Scale Command
438	0 to 100	Program 4: Pressure Breakpoint Preset
439	0 to 7	Program 4: Pressure Breakpoint Source

Table 5: Flow with Pressure Limit Programs

Function Programs 3 and 4 provide for Flow with Pressure Limit Control. Program 3 is configured in program items 420 through 429 in the Program 3 Form. Program 4 is configured in program items 430 through 439 in the Program 4 Form.

Flow Command Preset: The Flow Command Preset allows for direct numeric input for the control program. The preset is configured as a percentage, with 0% being equivalent to a 0VDC input signal and 100% being equivalent to a +10VDC signal.

Pressure Limit Preset: The Pressure Limit Preset allows for direct numeric input for the control program. The preset is configured as a percentage, with 0% being equivalent to a 0VDC input signal and 100% being equivalent to a +10VDC signal.

Flow Command Source: The Flow Command Source selects the source of the flow command for the program. Valid entries are (0) Preset Value, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3), (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If the Preset Value is chosen, the Flow Command Preset is used as the flow command.

Pressure Limit Source: The Pressure Limit Source selects the source of the pressure limit command for the program. Valid entries are (0) Preset Value, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If the Preset Value is chosen, the Pressure Limit Preset is used as the pressure limit command.

Pressure Feedback Source: The Pressure Feedback Source selects the source of the pressure feedback for the program. Valid entries are (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1.

Program Output Destination: The Program Output Destination selects the output of the program. Valid entries are (0) Pump Controller or (1) Direct. If the Pump Controller is chosen, the output of the Program will be the input to the Pump Controller module. If Direct is chosen, the output of the Program will by-pass the Pump Controller module and is passed directly to the servo driver. Under most circumstances, the Pump Controller should be chosen as the output destination.

KP: KP provides the proportional gain setting to control the pressure limit slope. KP is configured as a percentage, with 0% to no proportional gain and 100% equivalent to maximum proportional gain.

Pressure Breakpoint Preset: The Pressure Breakpoint Preset allows for direct numeric input. The preset has a slightly different characteristics depending on the value of its entry.

If the Pressure Breakpoint Source is set to **0 (Preset Value)**, the preset is configured as a percentage, with 0% equivalent to a 0VDC input signal and 100% equivalent to a +10VDC signal. This value is used as the Pressure Breakpoint command.

If the Pressure Breakpoint Source is set to **6 (Limit Offset)**, the preset is configured as a percentage, with 0% equivalent to a 0VDC input signal and 100% equivalent to a -10VDC offset signal. The offset value is added to the Pressure Limit Source signal to make the Pressure Breakpoint command.

Finally, if the Pressure Breakpoint Source is set to **7 (Limit Attenuation)**, the preset is configured as a percentage of the Pressure Limit Source, with 0% equivalent to a 0VDC input signal and 100% equivalent to the Pressure Limit Source. This value is used as the Pressure Breakpoint command.

Pressure Breakpoint Source: The Pressure Breakpoint Source selects the source of Pressure Breakpoint command. Valid entries are (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), (5) Ramp 1, (6) Limit Offset, (7) Limit Attenuation, (8) Reference Offset or (9) Reference Attenuation.

Program Overview: The Flow with Pressure Limit Control Program is a sloping pressure limiting control program similar to the control schemes used in Oilgear Analog Rack systems.

The algorithm will begin to limit the Flow command once the Pressure Feedback value is greater than the Pressure Breakpoint command. Comparing the Breakpoint command to the Feedback value produces an error value. The error is multiplied by the KP constant to produce the Yp limit signal, which is summed with the full-scale command. The summation of the full-scale command and the YP limit signal in turn sets a limit to the Flow command. If the Breakpoint Pressure Limit command is greater than the Feedback signal, the Flow command will only be limited by the full-scale command .

If using EPC software version 1.06 or earlier, see Appendix A for Generation 1 control.

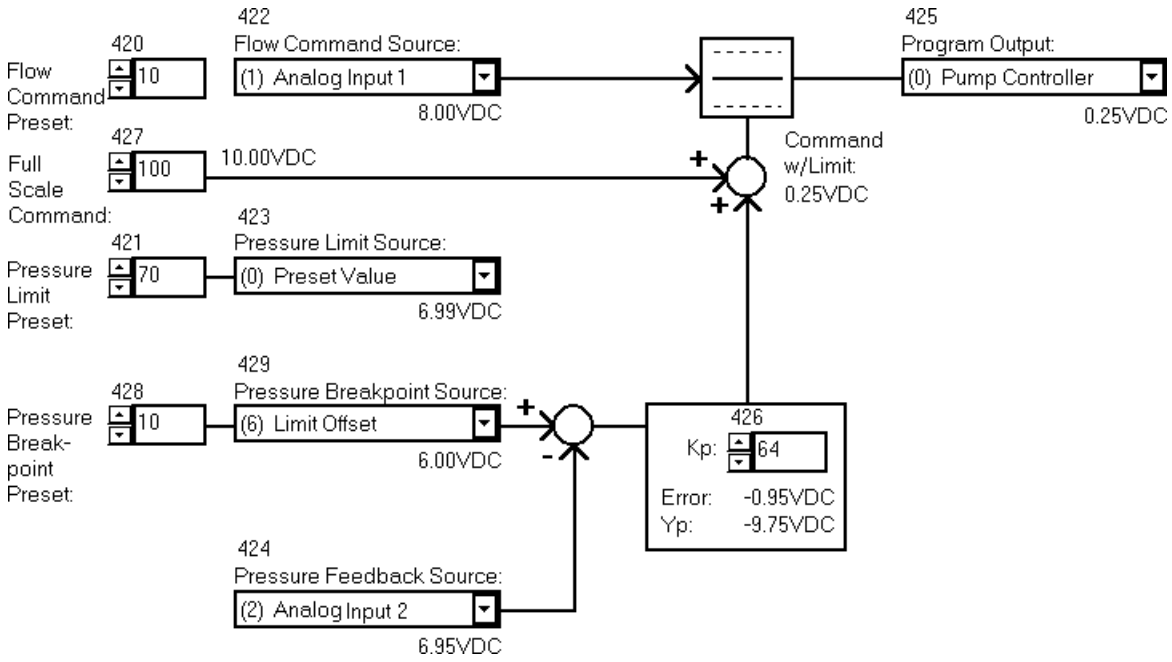

Figure 5: Flow with Pressure Limit Program

Example: Figure 5 shows Program 3 Form for Flow with Pressure Limit. The Flow Command Source is Analog Input 1 (program item 422=1). The Flow Command Preset is set to 10% (program item 420=10) although the Flow Command Preset is not used in this example.

The Pressure Limit Source command is the Preset Value (program item 423=0), therefore the pressure limit command is set at a 70% level (program item 421=70). The Pressure Feedback Source is Analog Input 2 (program item 424=2).

The Pressure Breakpoint Source is Limit Offset (program item 429=6). The Pressure Breakpoint Preset is set to 10% (program item 428=10). The Pressure Breakpoint value is the Pressure Limit minus the Pressure Breakpoint Preset: 7.00V-1.00V = 6.00V. Note there is a slight conversion error in this example. The Pressure Limit Preset is 70 but at the Pressure Limit Source it is 6.99V instead of 7.00V.

The error signal is produced by comparing the Pressure Breakpoint Source to the Feedback signal: 6.00V - 6.95V = -0.95V. The error is multiplied by the KP constant to produce the Yp limit -0.95V x 10.26 = -9.75V. A KP value of 64 equals a 10.26 KP constant.

The Pressure Limit command is summed with the Full-Scale command to set the limit for the Flow command: 10.0V - 9.75V = 0.25V. Finally, the Program Output is set to the Pump Controller (program item 425=0).

4.2.5 Load Sense Control Programs (44x, 45x)

Program Item	Range	Description
440	1 to 100	Program 5: Pressure Point 2 Preset
441	1 to 100	Program 5: Delta Pressure Preset
442	1 to 100	Program 5: Pressure Limit Preset
443	0 to 5	Program 5: Pressure Point 2 Source
444	0 to 5	Program 5: Delta Pressure Source
445	0 to 5	Program 5: Pressure Limit Source
446	1 to 5	Program 5: Pressure Point 1 Source
447	0 to 1	Program 5: Program Output Destination
448	0 to 100	Program 5: KP
449	0 to 100	Program 5: KI
450	1 to 100	Program 6: Pressure Point 2 Preset
451	1 to 100	Program 6: Delta Pressure Preset
452	1 to 100	Program 6: Pressure Limit Preset
453	0 to 5	Program 6: Pressure Point 2 Source
454	0 to 5	Program 6: Delta Pressure Source
455	0 to 5	Program 6: Pressure Limit Source
456	1 to 5	Program 6: Pressure Point 1 Source
457	0 to 1	Program 6: Program Output Destination
458	0 to 100	Program 6: KP
459	0 to 100	Program 6: KI

Table 6: Load Sense Programs Configuration

Function Programs 5 and 6 provide for Load Sense Control. Program 5 is configured in program items 440 through 449 from the Program 5 Form. Program 6 is configured in program items 450 through 459 from the Program 6 Form.

Pressure Point 2 Preset: The Pressure Point 2 Preset allows for direct numeric input for the control program. The preset is configured as a percentage, with 0% being equivalent to a 0VDC input signal and 100% being equivalent to a +10VDC signal.

Delta Pressure Preset: The Delta Pressure Preset allows for direct numeric input for the control program. The preset is configured as a percentage, with 0% being equivalent to a 0VDC input signal and 100% being equivalent to a +10VDC signal.

Pressure Limit Preset: The Pressure Limit Preset allows for direct numeric input for the control program. The preset is configured as a percentage, with 0% being equivalent to a 0VDC input signal and 100% being equivalent to a +10VDC signal.

Pressure Point 2 Source: The Pressure Point 2 Source selects the source of the pressure point 2 signal for the program. Valid entries are (0) Preset Value, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If the Preset Value is chosen, the Pressure Point 2 Preset is used as the delta pressure point 2 command.

Delta Pressure Source: The Delta Pressure Source selects the source of the delta pressure signal for the program. Valid entries are (0) Preset Value, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3), (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If the Preset Value is chosen, the Delta Pressure Preset is used as the delta pressure command.

Pressure Limit Source: The Pressure Limit Source selects the source of the pressure limit command for the program. Valid entries are (0) Preset Value, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If the Preset Value is chosen, the Pressure Limit Preset is used as the pressure limit command.

Pressure Point 1 Source: The Pressure Point 1 Source selects the source of the pressure feedback for the program. Valid entries are (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1.

Program Output Destination: The Program Output Destination selects the output of the program. Valid entries are (0) Pump Controller or (1) Direct. If the Pump Controller is chosen, the output of the Program will be the input to the Pump Controller module. If Direct is chosen, the output of the Program will by-pass the Pump Controller module and is passed directly to the servo driver. Under most circumstances, the Pump Controller should be chosen as the output destination.

KP and **KI**: KP and KI provide the proportional and integral constants, respectively, for the PI control algorithm. Both terms are expressed as 0 to 100% of a maximum value. The PI control loop can be made a P-only control loop by setting the KI term to 0. Likewise, the PI control loop can be made an I-only control loop by setting the KP term to 0.

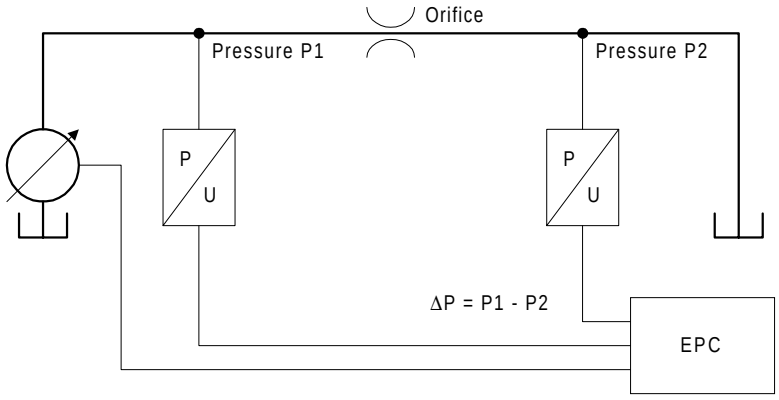

Figure 6: Load Sense Circuit

Program Overview: The Load Sense Control Program is one of the more complex control algorithms supplied with the EPC. The goal of the load sense control is to maintain a pressure difference across an orifice (refer to Figure 6). Typically, two pressure transducers would be used to monitor two points in the hydraulic circuit. The pump flow would be controlled such that ΔP = P1 - P2.

In addition to this basic control, a pressure limiter is added to ensure that the down-flow pressure at P2 does not reach a critical point. The controller command is the sum of the Point 2 Pressure and Delta Pressure signals, limited by the Pressure Limit Command. Comparing this command with the Point 1 Pressure signal results in an error value. The error is multiplied by the KP and KI constants to produce the Yp and Yi contributions to the program output signal.

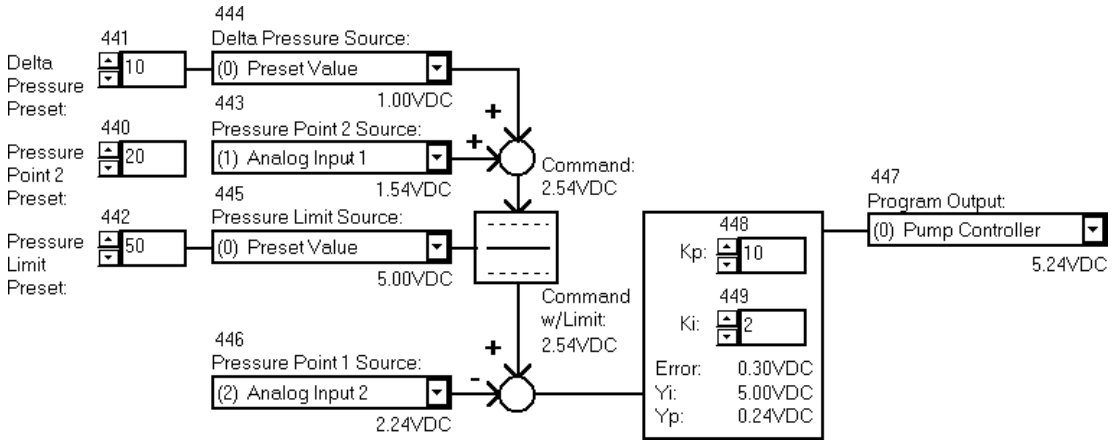

Figure 7: Load Sense Program

Example: Figure 7 shows Program 5 Form for Load Sense. The Delta Pressure Source is set to the Delta Pressure Preset Value of 10% (program item 444=0 and program item 441=10). The Pressure Point 2 Source is Analog Input 1 (program item 443=1), therefore the command is 1.00V +1.54V = 2.54V.

The Pressure Limit Source is set to the Pressure Limit Preset Value of 50% (program item 445=0 and program item 442=50). In this case, the previous command value is not limited, since the command (2.54V) is less than the Pressure Limit Command (5.00V).

The error signal is produced by comparing the Command to the Pressure Point 1 signals: 2.54V - 2.24V = 0.30V. The Yi and Yp signals are produced from the PI controller and the Program Output is roughly equal to their sum: 5.00V + 0.24V = 5.24V. The Program Output is set to the Pump Controller (program item 447=0).

4.2.6 Simple Flow Control Programs (46x, 47x)

Program Item	Range	Description
460	0 to 100	Program 7: Flow Command Preset
461	0 to 5	Program 7: Flow Command Source
464	0 to 1	Program 7: Program Output Destination
470	0 to 100	Program 8: Flow Command Preset
471	0 to 5	Program 8: Flow Command Source
474	0 to 1	Program 8: Program Output Destination

Table 7: Simple Flow Programs Configuration

Function Programs 7 and 8 provide for Simple Flow Control. Program 7 is configured in program items 460 through 464 from the Program 7 Form. Program 8 is configured in program items 470 through 474 from the Program 8 Form.

Flow Command Preset: The Flow Command Preset allows for direct numeric input for the control program. The preset is configured as a percentage, with 0% being equivalent to a 0VDC input signal and 100% being equivalent to a +10VDC signal.

Flow Command Source: The Flow Command Source selects the source of the flow command for the program. Valid entries are (0) Preset Value, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If the Preset Value is chosen, the Flow Command Preset is used as the flow command.

Program Output Destination: The Program Output Destination selects the output of the program. Valid entries are (0) Pump Controller or (1) Direct. If the Pump Controller is chosen, the output of the Program will be the input to the Pump Controller module. If Direct is chosen, the output of the Program will by-pass the Pump Controller module and passed directly to the servo driver. Under most circumstances, the Pump Controller should be chosen as the output destination.

Program Overview: The Simple Flow Control Program is by far the least complex control algorithm. In fact in does little more than transfer an analog or fixed input directly to the Pump Controller.

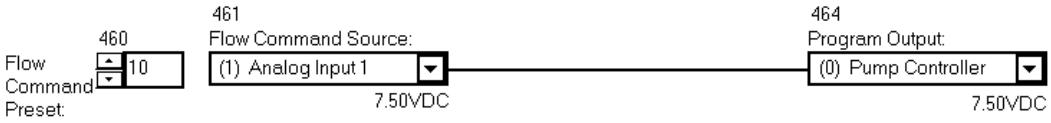

Figure 8: Simple Flow Program

Example: Figure 8 shows the Program 7 Form for Flow Control. The Flow Command Source is Analog Input 1 (program item 461=1). The Flow Command Preset is set to 10% (program item 460=10) although the preset is not used in this example. The Program Output is set to the Pump Controller (program item 464=0).

4.2.7 Pressure Control with Flow Preset Programs - Generation 2 (48x, 49x)

Program Item	Range	Description
480	0 to 100	Program 9: Flow Command Preset
481	1 to 100	Program 9: Pressure Command Preset
482	0 to 5	Program 9: Flow Command Source
483	0 to 5	Program 9: Pressure Command Source
484	1 to 5	Program 9: Pressure Feedback Source
485	0 to 1	Program 9: Program Output Destination
486	0 to 100	Program 9: KP
487	0 to 100	Program 9: KI
488	0 to 100	Program 9: Q to P Control Switch Preset
489	0 to 7	Program 9: Q to P Control Switch Source
490	0 to 100	Program 10: Flow Command Preset
491	1 to 100	Program 10: Pressure Command Preset
492	0 to 5	Program 10: Flow Command Source
493	0 to 5	Program 10: Pressure Command Source
494	1 to 5	Program 10: Pressure Feedback Source
495	0 to 1	Program 10: Program Output Destination
496	0 to 100	Program 10: KP
497	0 to 100	Program 10: KI
498	0 to 100	Program 10: Q to P Control Switch Preset
499	0 to 7	Program 10: Q to P Control Switch Source

Table 8: Pressure Control with Flow Preset Programs

Function Programs 9 and 10 provide for Pressure Control with Flow Preset. Program 9 is configured in program items 480 through 489 in the Program 9 Form. Program 10 is configured in program items 490 through 499 in the Program 10 Form.

Flow Command Preset: The Flow Command Preset allows for direct numeric input for the control program. The preset is configured as a percentage, with 0% being equivalent to a 0VDC input signal and 100% being equivalent to a +10VDC signal.

Pressure Command Preset: The Pressure Command Preset allows for direct numeric input for the control program. The preset is configured as a percentage, with 0% being equivalent to a 0VDC input signal and 100% being equivalent to a +10VDC signal.

Flow Command Source: The Flow Command Source selects the source of the flow command for the program. Valid entries are (0) Preset Value, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3), (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If the Preset Value is chosen, the Flow Command Preset is used as the Flow command.

Pressure Command Source: The Pressure Command Source selects the source of the pressure command for the program. Valid entries are (0) Preset Value, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If the Preset Value is chosen, the Pressure Command Preset is used as the Pressure command.

Pressure Feedback Source: The Pressure Feedback Source selects the source of the pressure feedback for the program. Valid entries are (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1.

Program Output Destination: The Program Output Destination selects the output of the program. Valid entries are (0) Pump Controller or (1) Direct. If the Pump Controller is chosen, the output of the Program will be the input to the Pump Controller module. If Direct is chosen, the output of the Program will by-pass the Pump Controller module and is passed directly to the servo driver. Under most circumstances, the Pump Controller should be chosen as the output destination.

KP: KP provides the proportional gain setting to control the pressure limit slope. KP is configured as a percentage, with 0% to no integral gain and 100% equivalent to maximum proportional gain.

KI: KI provides the integral gain setting to PI control loop of the program. KI is configured as a percentage, with 0% to no proportional gain and 100% equivalent to maximum integral gain.

Q to P Control Switch Preset: The Q to P Control Switch Preset allows for direct numeric input. The preset has a slightly different characteristics depending on the value of Q to P Control Switch Source entry.

If the Q to P Control Switch Source is set to **0 (Preset Value)**, the preset is configured as a percentage, with 0% equivalent to a 0VDC input signal and 100% equivalent to a +10VDC signal. This value is used as the toggle point between Pressure and Flow control.

If the Q to P Control Switch Source is set to **6 (Limit Offset)**, the Preset is configured as a percentage, with 0% equivalent to a 0VDC input signal and 100% equivalent to a -10VDC offset signal. The offset value is added to the Pressure Command Source signal to make the Toggle Point between Pressure and Flow control.

Finally, if the Q to P Control Switch Source is set to **7 (Limit Attenuation)**, the Preset is configured as a percentage, and the Control Switch Toggle Point will be equal to the percentage of the Pressure Command signal.

Q to P Control Switch Source: The Q to P Control Switch Source selects the source of the Flow to Pressure Toggle Point command. Valid entries are (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), (5) Ramp 1, (6) Limit Offset or (7) Limit Attenuation.

Program Overview: The Pressure with Flow Preset Control Program functions as either Flow Control or Pressure Control, depending on whether the feedback pressure is greater or less than the Q to P Control Switch signal.

Under most circumstances, the control begins as a Flow Control. The algorithm will switch from a Flow Control to Pressure Control once the feedback pressure signal is greater than the Q to P Control Switch command. Once in Pressure Control, the Pressure command is compared to the feedback value to produce an error value. The error is multiplied by the KP and KI constants to produce the Yp and Yi contributions of the program output. In the pressure mode, the Flow command acts as a limit to the pressure control loop.

If using EPC software version 1.06 or earlier, see Appendix A for Generation 1 control.

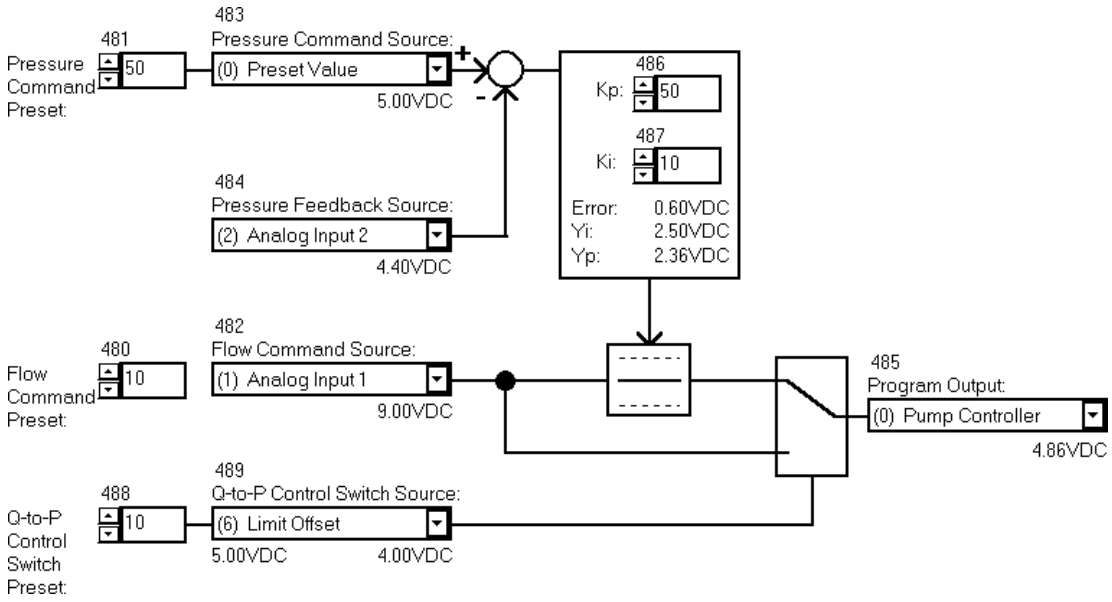

Figure 9: Pressure Control with Flow Preset Program in Pressure Mode

Example: Figure 9 shows Program 9 Form for Pressure Control with Flow Preset in Pressure Mode. The Flow Command Source is Analog Input 1 (program item 482=1). The Flow Command Preset is set to 10% (program item 480=10) although the Flow Command Preset is not used in this example.

The Pressure Command Source command is the Preset Value (program item 483=0), therefore the pressure limit command is set at a 50% level (program item 481=50). The Pressure Feedback Source is Analog Input 2 (program item 484=2).

The Q to P Control Switch Source is Limit Offset (program item 489=6). The Q to P Control Switch Preset is set to 10% (program item 488=10), therefore the Q to P Toggle Point is 5.00V - 1.00V = 4.00V.

The error signal is produced by comparing the Pressure Command Source to the Feedback signal: 5.00V - 4.40V = 0.60V. The Yi and Yp signals are produced from the PI controller and the Pressure command is roughly equal to their sum: 2.50V + 2.36V = 4.86V.

Since the Pressure Feedback (4.40V) is greater than the Q to P Control Switch (4.00V), the program is in Pressure Control. The Pressure command is limited by the Flow command. Since the Pressure command (4.86V) is less than the Flow command (9.00V), it is not limited. Finally, the Program Output is set to the Pump Controller (program item 425=0).

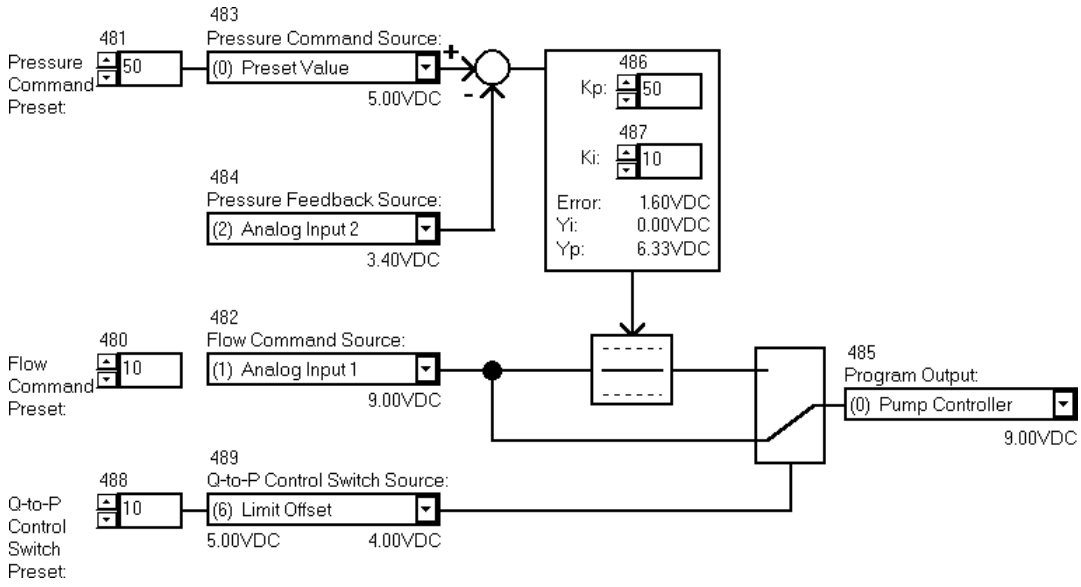

Figure 10: Pressure Control with Flow Preset Program in Flow Mode

Example: Figure 10 shows Program 9 Form for Pressure Control with Flow Preset in the Flow Mode. The Flow Command Source is Analog Input 1 (program item 482=1). The Flow Command Preset is set to 10% (program item 480=10) although the Flow Command Preset is not used in this example.

The Q to P Control Switch Source is Limit Offset (program item 489=6). The Q to P Control Switch Preset is set to 10% (program item 488=10), therefore the Q to P Toggle Point is 5.00V - 1.00V = 4.00V.

The error signal is produced by comparing the Pressure Command Source to the Feedback signal: 5.00V - 3.40V = 1.60V. The Yi and Yp signals are produced from the PI controller and the Pressure Command is roughly equal to their sum: 0.00V + 6.33V = 6.33V.

Since the Pressure Feedback (3.40V) is less than the Q to P Control Switch (4.00V), the program is in Flow Control. The Flow Command (9.00V) is simply passed through to the Program Output. Finally, the Program Output is set to the Pump Controller (program item 425=0).

4.2.8 Advanced Control with Feed-Forward Programs - (50x, 51x)

Program Item	Range	Description
500	1 to 100	Program 11: Command Preset
501	0 to 5	Program 11: Command Source
502	1 to 5	Program 11: Feedback Source
503	0 to 1	Program 11: Program Output Destination
504	-10 to 10	Program 11: Command Offset
505	0.06 to 2	Program 11: Command Gain
506	0 to 100	Program 11: KP
507	0 to 100	Program 11: KI
510	1 to 100	Program 12: Command Preset
511	0 to 5	Program 12: Command Source
512	1 to 5	Program 12: Feedback Source
513	0 to 1	Program 12: Program Output Destination
514	-10 to 10	Program 12: Command Offset
515	0.06 to 2	Program 12: Command Gain
516	0 to 100	Program 12: KP
517	0 to 100	Program 12: KI

Table 9: Advanced Control with Feed-Forward Programs

Function Programs 11 and 12 provide for Advanced Control with Feed-Forward. Program 11 is configured in program items 500 through 507 in the Program 11 Form. Program 12 is configured in program items 510 through 517 in the Program 12 Form.

Command Preset: The Command Preset allows for direct numeric input for the control program. The preset is configured as a percentage, with 0% being equivalent to a 0VDC input signal and 100% being equivalent to a +10VDC signal.

Command Source: The Command Source selects the source of the command for the program. Valid entries are (0) Preset Value, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3), (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If the Preset Value is chosen, the Command Preset is used as the Command.

Feedback Source: The Feedback Source selects the source of feedback for the program. Valid entries are (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1.

Program Output Destination: The Program Output Destination selects the output of the program. Valid entries are (0) Pump Controller or (1) Direct. If the Pump Controller is chosen, the output of the Program will be the input to the Pump Controller module. If Direct is chosen, the output of the Program will by-pass the Pump Controller module and is passed directly to the servo driver. Under most circumstances, the Pump Controller should be chosen as the output destination.

Command Offset: The Command Offset is used to apply a voltage offset to the Command Signal of the program. The voltage offset can be in the range of -10VDC to +10VDC in 0.1VDC increments, although the resulting signal can not extend beyond the maximum input range of -10VDC to +10VDC. The resulting signal multiplied the Command Gain, determines the Open Loop or Feed-Forward signal for the program.

Command Gain: The Command Gain is used to apply a voltage gain to the Command Signal after the Command Offset Voltage is applied. The voltage gain can be in the range of 0.0625 attenuation to x2 gain in 0.0625 increments, although the resulting signal can not extend beyond the maximum input range of -10VDC to +10VDC. The resulting signal determines the Open Loop or Feed-Forward signal for the program.

KP: KP provides the proportional gain setting to PI control loop of the program. KP is configured as a percentage, with 0% to no proportional gain and 100% equivalent to maximum proportional gain.

KI: KI provides the integral gain setting to PI control loop of the program. KI is configured as a percentage, with 0% to no integral gain and 100% equivalent to maximum integral gain.

Open Loop: The program is in Open Loop only when the Mode Selection (200) is in the Static Mode and the digital input is low.

Closed Loop: The program is in Closed Loop when the Mode Selection (200) is in the Static Mode with the digital input high or in the Dynamic Mode.

Program Overview: The Advanced Control with Feed-Forward Program in Closed Loop is a PI control with an adjustable Feed-Forward signal. Comparing the command to the feedback values produces an error value. The error is multiplied by the KP and KI constants to produce the YP and YI contributions of the PI controller. This signal is then summed with the feed-forward signal to produce the output signal.

The Advanced Control with Feed-Forward Program in Open Loop simply modifies a command with a offset and gain producing a output signal. The PI control is not used.

If using EPC software version prior to 1.10, this program is not available.

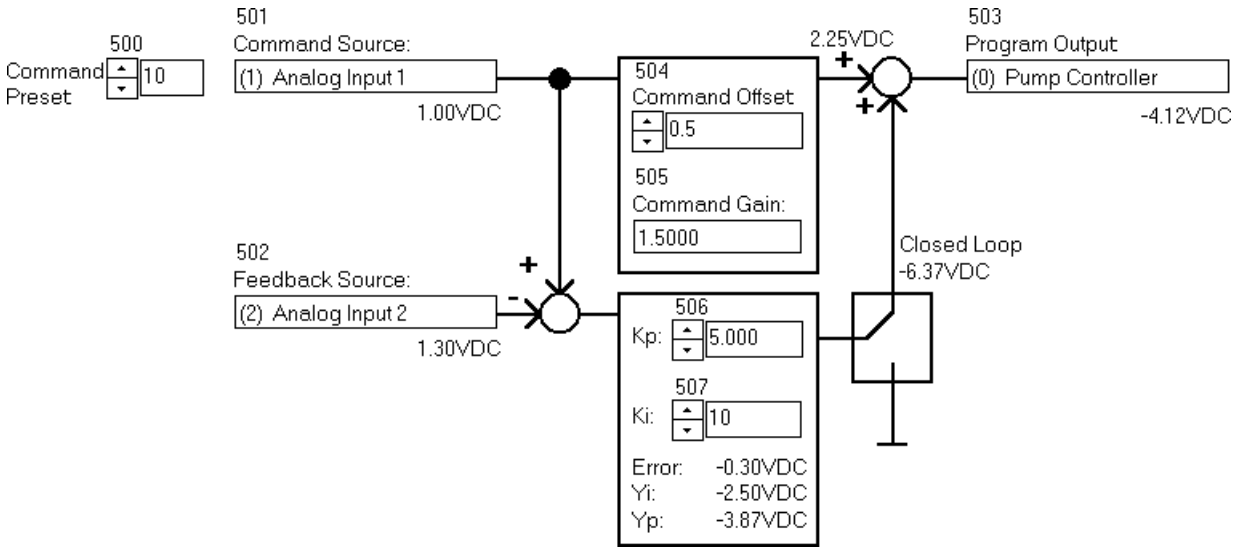

Figure 11: Advanced Control with Feed-Forward Program in Closed Loop

Example: Figure 11 shows Program 11 Form for Advanced Control with Feed-Forward in Closed Loop. The Command Source is Analog Input 1 (program item 501=1). The Command Preset is set to 10% (program item 500=10) although the Command Preset is not used in this example.

The Feedback Source is Analog Input 2 (program item 502=2).

The error signal is produced by comparing the Command Source to the Feedback signal: 1.00V - 1.30V = -0.30V. The Yi and Yp signals are produced from the PI controller and the PI controller output command is roughly equal to their sum: -2.50V + (-3.87V) = -6.37V.

The Command is offset and multipied by the gain: (1.00V + 0.5V) x 1.5 = 2.25V. This Feed-Forward Command is then summed with PI control output: 2.25V +(-6.37V) = -4.12V. Finally, the Program Output is set to the Pump Controller (program item 503=0).

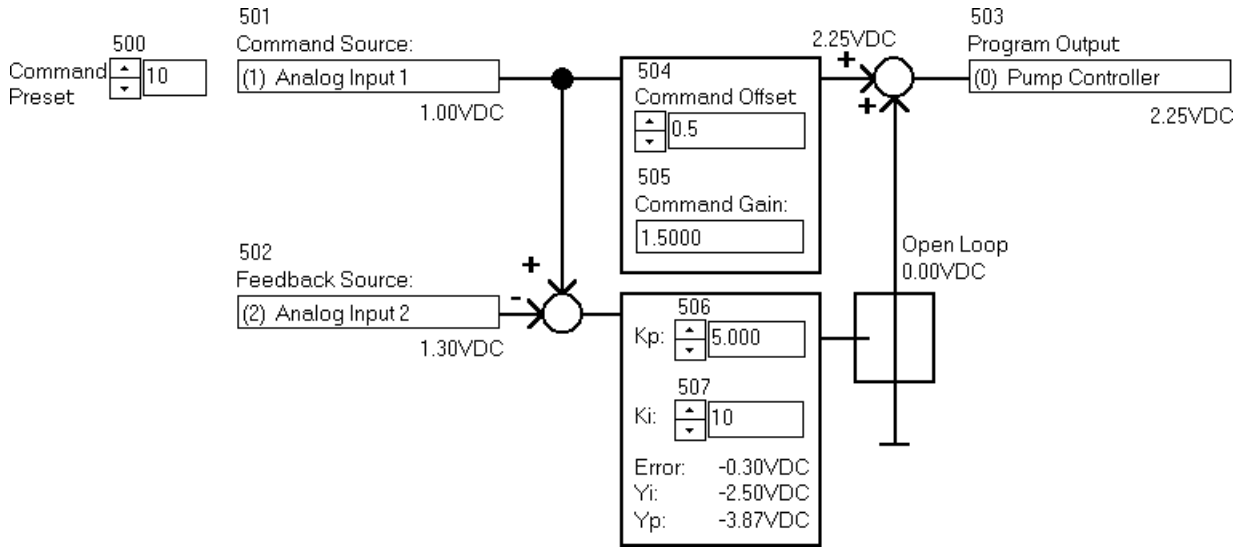

Figure 12: Advanced Control with Feed-Forward Program in Open Loop

Example: Figure 12 shows Program 11 Form for Advanced Control with Feed-Forward in Open Loop. The Command is offset and multipied by the gain: (1.00V + 0.5V) x 1.5 = 2.25V. This Feed-Forward Command is then summed with the Open Loop output: 2.25V +0.0V = 2.25V. Finally, the Program Output is set to the Pump Controller (program item 503=0).

4.3 Pump Controller Configuration

4.3.1 Overview

The Pump Controller provides the basic functionality of the module: to provide closed loop stroke feedback control for the servo valve. In addition to stroke feedback, the Pump Controller module can be configured for horsepower limitation.

Under usual circumstances, the pre-defined programs are used as outer loop control while the Pump Controller provides inner loop control. The output of the pre-defined programs is very nearly always passed through to the Pump Controller module (refer to Section 4.2.1 for an overview of the pre-defined Program modules).

4.3.2 Configuration

Program Item	Range	Description
800	0 to 5	Pump Controller and HP Limiter: Stroke Feedback Source
801	0 to 100	Pump Controller: Function Zero Stroke Command
802	0 to 1	Pump Controller: Output Polarity
803	15 to 100	Pump Controller: Output Current Limit
804	0 to 100	Pump Controller: KP
805	0 to 100	Pump Controller: KI
810	0 to 100	HP Limiter: Reference
811	0 to 5	HP Limiter: Pressure Feedback Source
812		HP Limiter: Spare
813	0 to 100	HP Limiter: KP
814	0 to 100	HP Limiter:
875	0 to 255	Dither

Table 10: Pump Controller Configuration

4.3.2.1 Function Zero Stroke Command

Normally, the Active Program Block provides the command to the Pump Controller. For certain applications, it might be desirable to have the ability to switch between two function programs, and the EPC provides that feature by allowing two program blocks selectable by the digital input.

In some circumstances, a second program is not needed but some type of state is desired. A prime example would be a stand-by mode in which a fixed stroke would be commanded. In this circumstance, the user could place a pre-defined program in block 1 and select program 0 for block 2 (please refer to Section 4.1.3 regarding Program Block Configuration (21x).

The Function Zero Stroke Command is configured by program item 801 or from the Pump Controller Form. It is expressed as a value from 0 to 100%, where 0 equals full negative current, 100 equals full positive current, and 50 represents neutral or no current. A Function Zero Stroke Command of 75, for instance, would provide a 50% stroke command to the valve.

4.3.2.2 Stroke Controller

The Stroke Controller portion of the Pump Controller is configured by selecting a Stroke Feedback Source (program item 800) and setting values for KP (program item 804) and KI (program item 805) for the Stroke PI Controller. These values can be optimal adjusted from the Pump Controller Form.

Stroke Feedback Device: The Stroke Feedback Device determines which signal the command to the Stroke Controller is compared to. Valid entries are (0) Open Loop, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If Open Loop is chosen, the stroke controller is disabled and the command is passed directly through to the output.

KP and **KI**: KP and KI provide the proportional and integral constants, respectively, for the PI control algorithm. Both terms are expressed as 0 to 100% of a maximum value. The PI control loop can be made a P-only control loop by setting the KI term to 0. Likewise, the PI control loop can be made an I-only control loop by setting the KP term to 0.

The command to the stroke controller is from either the Active Program or the Function Zero Stroke Command (or by the HP-limited adjustment of this command, please refer to Section 4.3.2.3). An error signal is produced by comparison of this command to the stroke feedback signal. The PI loop produces Yp and Yi, determined by the error signal and the KP and KI constants, respectively. The stroke controller output is made by the summation of Yp and Yi. The Stroke Controller is disabled if the Stroke Feedback Source (program item 800) is selected as Open Loop.

The Pump controller relies on the stroke feedback device being configured correctly. Please refer to Section 4.4.5 regarding the LVDT Adjustment Algorithm.

4.3.2.3 HP Limiter

The HP Limiter can be configured to limit the command to the stroke controller (refer to Section 4.3.2.2). This portion of the Pump Controller is configured by selecting a Stroke Feedback Source (program item 800), Pressure Feedback Device (program item 811) and setting values for KP (program item 813) and KI (program item 814) for the HP Limiter PI Controller. Additionally, a HP Limit Factor (program item 810) must be entered (please refer to Section 4.6.2 regarding the HP Limit Factor Calculation). These values can be optimal adjusted from the Pump Controller Form.

Stroke Feedback Source: The Stroke Feedback Source determines which stroke signal is used in the HP calculation (this is the same stroke feedback used in the Stroke Controller, refer to Section 4.3.2.2). Valid entries are (0) Open Loop, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If Open Loop is chosen, the stroke controller is inactive, but the HP Limiter can be active, as long as a Pressure Feedback Source is configured. In this case, the module uses the pump controller command as the stroke feedback.

Pressure Feedback Source: The Pressure Feedback Source determines which pressure signal is used in the HP calculation. Valid entries are (0) No HP Limit, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If No HP Limit is chosen, the HP Limiter is inactive and the pump controller command will be passed directly to the stroke controller.

KP and **KI**: KP and KI provide the proportional and integral constants, respectively, for the PI control algorithm. Both terms are expressed as 0 to 100% of a maximum value. The PI control loop can be made a P-only control loop by setting the KI term to 0. Likewise, the PI control loop can be made an I-only control loop by setting the KP term to 0.

The product of Pressure and Stroke signals is compared to the HP Limit Factor (program item 810). If the product is greater than the factor, the feedback HP is greater than the allowed HP, and the pump controller command is adjusted through the Yp and Yi contributions of the HP Limiter PI controller. The HP Limiter works only as a limiter; the pump controller command is not manipulated if the HP Limit Factor is greater than the calculated HP.

The HP Limiter relies on the **HP Limit Factor** being configured correctly. Please refer to Section 4.5.1 regarding the HP Limit Factor Calculation.

4.3.2.4 Output Polarity

Module Polarity is selected from program item 802 from the Pump Controller Form. Polarity (program item 802) is either (0) Normal or (1) Inverted.

4.3.2.5 Output Current Limit

The Module can be current limited to protect the valve or limit stroke. The current limit is selected from program item 803 of the Pump Controller Form and is expressed as 0 to 100% of the maximum current of the module (250mA).

Current is limited in each direction, so a Current Limit of 50% will limit the current to -50% to +50% of the maximum.

4.3.2.6 Dither

The EPC provides for a dither signal that is superimposed on the final output to the current driver. The dither is set from the Pump Controller Form (the dither option is only available for EPC modules with software version of 1.05 or later).

The dither frequency is fixed at 200Hz. The amplitude of the dither signal is expressed in DAC counts, with 0 equal to no dither and 255 equal to maximum dither (approximately 12.5% of maximum controller current).

Table 11 below shows several examples of dither values in DAC counts converted into percent (%) and current (mA) for EPC1. The maximum current for EPC1 is 250mA.

Dither (DAC count)	Dither (%)	Dither (mA)
0	0.0%	0.00mA
51	2.5%	6.26mA
102	5.0%	12.52mA
154	7.5%	18.75mA
208	10.0%	25.00mA
255	12.5%	31.25mA

Table 11: Dither Examples

4.3.3 Configuration Example

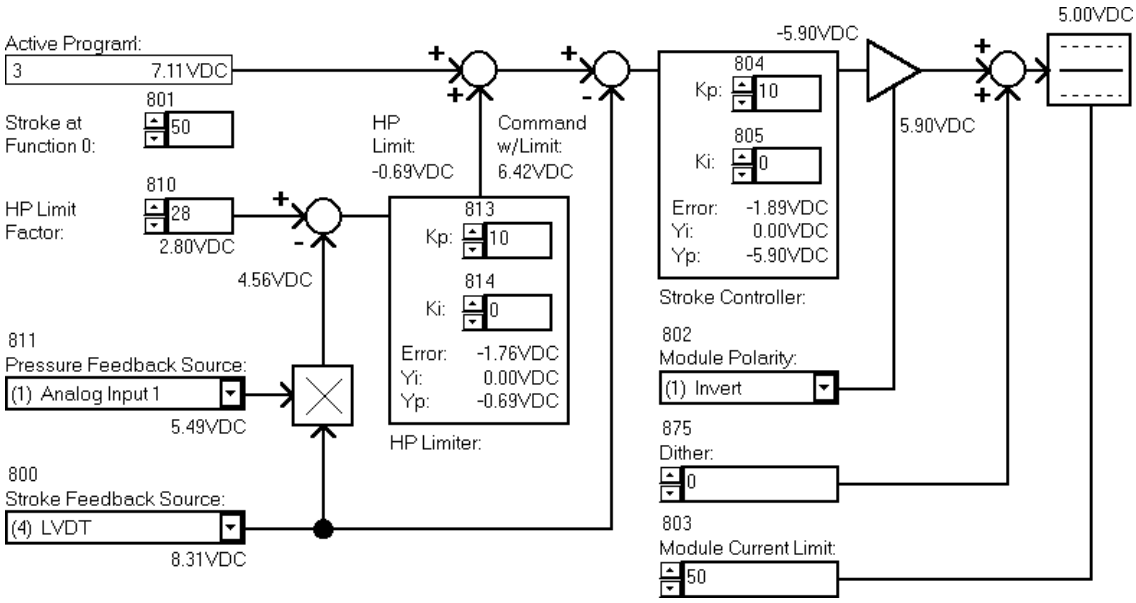

Figure 13: Pump Controller Configuration

Figure 13 shows the Pump Controller Module Form. The Diagnostic screen shows that Program 3 is active and passes the command of 7.11V to the Pump Controller. The Function Zero Stroke is set to 50% (program item 801=50), so if no program was active a neutral stroke would be the Pump Controller command signal.

The Pressure Feedback Source is Analog Input 1 (program item 811=1) and the Stroke Feedback Source is LVDT (program item 800=4). The internal HP calculation based on these pressure and stroke signals results in a value of 4.56V. The HP Limit Factor of 28% results in a value of 2.80V, so the actual HP is greater than the allowed HP. The error signal is the difference of these calculated numbers is 2.80V - 4.56V = -1.76V. The HP Limit is made up of the Yi and Yp contributions computed from the HP Limiter PI controller.

The resulting Command with HP Limit is 7.11V - 0.69V = 6.42V. This command, along with the Stroke Feedback signal is passed to the Stroke Controller, where the error signal is 6.42V - 8.31V = - 1.89V . This error signal is used for the Stroke Controller PI calculations, and the output is equal to the Yi and Yp contributions is 0.00V - 5.90V = -5.90V.

Module Polarity is set to Invert the module output (program item 802=1) so the -5.90V signal becomes 5.90V. Finally, the current is limited to 50% of maximum, so the 5.90V signal decreases to 5.00V.

4.4 Analog IO Configuration

The EPC module provides four Analog Inputs, two Analog Outputs and a Current Driver: Analog Inputs 1, 2 and 3 are referred to as General Purpose Analog Inputs and have a maximum input range of -10VDC to +10VDC. Analog Input 4 is usually referred to as LVDT Input. This input is intended for sinusoidal LVDT input. Analog Outputs 1 and 2 are programmable with a range of -10VDC to +10VDC. The Current Driver is either a Linear or PWM signal to drive a valve.

.

4.4.1 General Purpose Analog Input Configuration

Program Item	Range	Description
850	-10V to 10V	Analog Input 1: Offset
851	0.125 to 4	Analog Input 1: Gain
852	0 to 1	Analog Input 1: Polarity
853	0 to 1	Analog Input 1: Current Fault Enable
860	-10V to 10V	Analog Input 2: Offset
861	0.125 to 4	Analog Input 2: Gain
862	0 to 1	Analog Input 2: Polarity
863	0 to 1	Analog Input 2: Current Fault Enable
880	-10V to 10V	Analog Input 3: Offset
881	0.125 to 4	Analog Input 3: Gain
882	0 to 1	Analog Input 3: Polarity
883	0 to 1	Analog Input 3: Current Fault Enable

Table 12: General Purpose Analog Input Configuration

Program items 850 through 853 are used to configure Analog Input 1, program items 860 through 863 are used to configure Analog Input 2 and program items 880 through 883 are used to configure Analog Input 3. The Analog Inputs are configured from the Analog Input Configuration Form (select menu Diagnostics and then Analog IO Configuration).

Offset: A voltage offset can be applied to the Analog Input. The voltage offset can be in the range of -10VDC to +10VDC at 0.1VDC increments. The Analog IO Configuration Form allows for the direct entry of a voltage offset.

Gain: A limited gain factor can be applied to the Analog Inputs. Values in the range of a 0.125 attenuation to a × 4 gain at 0.125 increments are available. The Analog IO Configuration Form allows for the direct entry of a gain. Table 13 lists the 32 gains available.

Gain	Gain	Gain	Gain
0.125	1.125	2.125	3.125
0.250	1.250	2.250	3.250
0.375	1.375	2.375	3.375
0.500	1.500	2.500	3.500
0.625	1.625	2.625	3.625
0.750	1.750	2.750	3.750
0.875	1.875	2.875	3.875
1.000	2.000	3.000	4.000

Table 13: Analog Input Gain Settings

The resulting voltage is limited to the -10VDC to +10VDC range.

Polarity: The Polarity setting is set to either (0) Normal or (1) Inverted. Inverting the input in this way would be equivalent to reversing wire leads to the module. In fact, a better long term solution to using the invert setting would be to reverse the wire leads to the module.

Current Fault Enable: The Current Fault is set to either Disabled or Enabled and is designed for use when a 4-to-20mA input device is used. **The EPC module requires a 500Ω resistor across (in parallel) the Analog Input terminal pins (see Figure 20).** If used, a 4-to-20mA input device will result in a voltage from +2VDC (4mA) to +10VDC (20mA) to the module. If the Current Fault is enabled, the module will set a System Message if this voltage falls below +1.5VDC (approximately 3mA).

The four configuration settings are used together to configure the general purpose analog inputs. The order of monitoring/configuration is:

(1) A Fault is reported if the Current Mode Fault is enabled and the current supplied to the module falls below 3mA.
(2) Offset Voltage by Offset Setting.
(3) Multiply Voltage by Gain Setting.
(4) Invert Analog Input (if Polarity Invert set).

Example 1: A user wants a 4-20mA signal at Analog Input 1 to control a bi-directional pump (command range of +/- 10VDC).

First the user would enable the current fault for Analog Input 1 (program item 853=1) and place a 500 ohm resistor across the analog 1 input terminals. This will create a +2VDC to +10VDC voltage at the terminals and generate a fault if the voltage drops below 1.5VDC (3 mA).

Second, the user would set the Analog Input Offset to generate a –6VDC offset (program item 850= -6.0). This creates a –4VDC to +4VDC voltage from the original +2VDC to +10VDC voltage.

Next, the user would set the gain to 2.5 (program item 852=2.5). This creates a –10VDC to +10VDC voltage from the offset voltage of –4VDC to +4VDC.

Finally, the user would set the input polarity to normal (program item 852=0), so the input is not inverted. See Figure 14.

Example 2: A user wants a 0V to 5VDC signal at Analog Input 2 to control a unidirectional pump (command range of 0 to +10VDC).

First the user would disable the current fault for Analog Input 2 (program item 863=0).

Second, the user would configure the input for 0VDC voltage offset (program item 860=0) since the input voltage needs no offset for this particular example.

Next, the user would set the gain to 2 (program item 861=2) to create a 0 to +10VDC voltage from the offset voltage of 0 to +5VDC.

Finally, the user would set the input polarity to normal (program item 862=0), so the input is not inverted. See Figure 14.

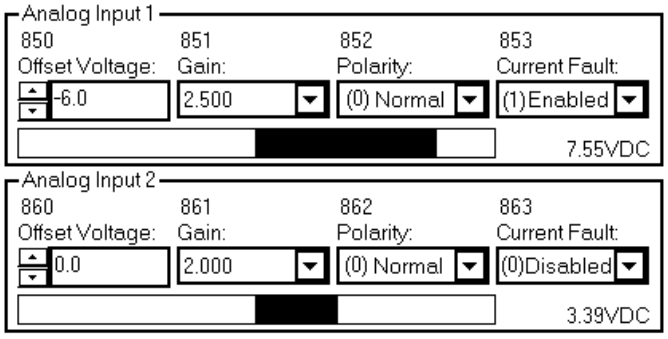

Figure 14: Analog Inputs Example

4.4.2 LVDT Fine-Adjustable Analog Input Configuration

Program Item	Range	Description
840	0 to 63	LVDT: Course Gain
841	0 to 63	LVDT: Fine Gain
843	0 to 1023	LVDT: Offset
845	0 to 1	LVDT: Polarity

Table 14: LVDT Input Configuration

Program items 840 through 845 are used to configure the LVDT. The LVDT Input is configured from the Analog IO Configuration Form (select menu Diagnostics and then Configuration). See Figure 15.

The adjust program item allows the module to be placed in **Pump Controller Adjust Mode**. This is a special operating mode designed for adjustment of the LVDT inputs. Please refer to Section 4.4.5 for a thorough discussion of this adjustment mode.

Course and Fine Gains: Since greater resolution is needed to scale and offset the input of the sinusoidal LVDT input signals, the gain and offset are not done directly in the microcontroller, but performed through electrical circuitry. The Course and Fine Gain increases over the range from 0 to 63. The LVDT should be configured using the algorithm discussed in Section 4.6.1.

Offset: The LVDT offset, like the course and fine gains, manipulates hardware circuitry. An offset setting ranges from 0 to 1023 to offset the LVDT from -10V to 10V. A 512 setting has a 0V offset. Please refer to Section 4.6.1 for a discussion of the LVDT Adjustment Algorithm.

Polarity: The Polarity setting is set to either (0) Normal or (1) Inverted. Inverting the input in this way would be equivalent to reversing wire leads to the module. In fact, a better long term solution to using the invert setting would be to reverse the wire leads to the module.

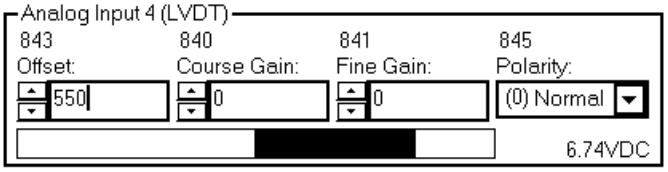

Figure 15: LVDT Input

4.4.3 Programmable Analog Outputs

There are 2 programmable analog outputs (see Figure 16). Analog Output 1 (program item 930) is located on the front of the EPC typically used as a test point for debugging. Analog Output 2 (program item 933) is located on terminals 7 and 8 typically connected to an analog input of a PLC.

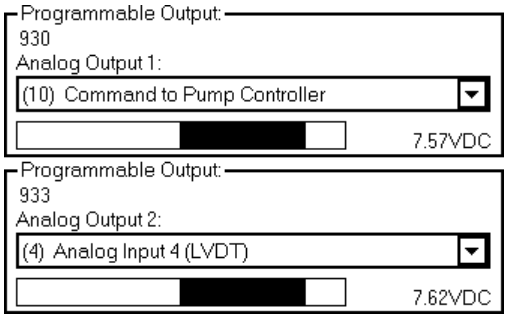

Figure 16: Analog Outputs

The test point can easily be monitored externally. The signals for the programmable outputs are selected in the Analog IO Configuration Form. Available Diagnostic signals are shown in Table 15.

Selection	Diagnostic
0	Output Disabled
1	Analog Input 1
2	Analog Input 2
3	Analog Input 3
4	Analog Input 4 (LVDT)
5	Current Feedback Signal
6	LVDT sine wave excitation signal
7	+12VDC Supply
8	-12VDC Supply
9	Servo Driver Output
10	Command to Pump Controller (Output of Active Function Program)
11	Ramp

Table 15: Diagnostic Signals

4.4.4 Servo Valve Driver with Stroke Feedback

The Servo Valve Driver Configuration allows for selecting the pump adjust mode, monitoring the driver current and stroke feedback, and scaling and offsetting the driver. The scaling and offsetting parameters are only available for EPC modules running firmware Version 1.10 or later. The Servo Driver information is located in the lower left corner of the Analog IO Configuration Form (see Figure 17).

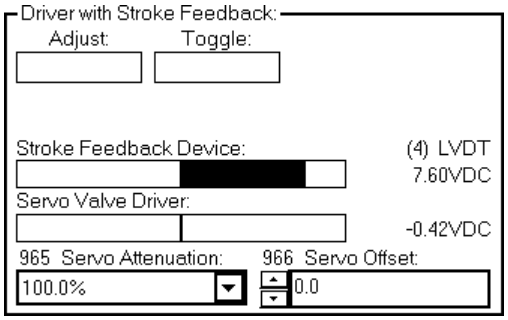

Figure: 17: Servo Valve Driver

4.4.4.1 Servo Attenuation and Offset

The Servo Driver **configuration** settings are used together with the Output Polarity and Output Current Limit from the Pump Controller Configuration Form to configure the servo driver output. The Configuration Settings are applied AFTER the Polarity setting and BEFORE the Current Limit Setting.

The Servo Driver **Attenuation** parameter (menu item 965) attenuates the servo driver signal. Valid entries are from 0.4% to 100% at approximately 0.4% increments. The Attenuation Setting is applied immediately AFTER the Polarity setting and BEFORE the Servo Driver Offset Setting.

The Servo Driver **Offset** parameter (menu item 966) applies an offset voltage to the servo driver signal. Valid entries are from -10.0VDC to +10.0VDC at 0.1VDC increments. The Offset Setting is applied immediately AFTER the Attenuation setting and BEFORE the Current Limit Setting.

The Servo Valve Driver **current** is shown in voltage units. The driver range of -10V to 10V is a scaled value of the output current. Depending on the EPC part number, the output current may be different for the same output voltage. See the table 16 for more information.

EPC P/N L723888-	Driver Current	Current @ -10V	Current @ -5V	Current @ 0V	Current @ 5V	Current @ 10V
110	+/-800mA	-800mA	-400mA	0mA	400mA	800mA
111	+/-800mA	-800mA	-400mA	0mA	400mA	800mA
112	+600mA	0mA	0mA	0mA	300mA	600mA
114	+/-250mA	-250mA	-125mA	0mA	125mA	250mA

Table 16: Driver Output

4.4.4.2 Stroke Feedback Device

The Stroke Feedback Device information is displayed in both a bargraph and numerical form. The Feedback Device is determined by menu item 800 located in the Pump Controller Form. Typically for pumps, Analog Input 4 (LVDT) is selected.

4.4.4.3 Adjustment Mode

The Pump Controller Adjust Mode is a special operation mode in which an Adjust Mode Toggle Command controls the servo driver rather than the Pump Controller or Active Function block.

The Adjust Mode works optimally with Main Pumps off and Pilot Pumps pressurized. Adjust mode is set by pressing the Adjust mode Command button from the Analog IO Configuration Form. Adjust mode is indicated by a System Message.

The Adjust Mode Toggle Command will alternately command neutral, full positive and full negative current to the driver. Initially, the output toggle is at the neutral (zero) current position.

The Adjustment toggle command is monitored from the PC interface. The Analog I/O Configuration Form has a toggle command button. The display and bar graph indicator will show the value of the toggle.

The **Adjust Mode Command Toggle** is a special function available in Adjustment mode that will alternately command neutral, full positive and full negative current to the driver. If in Adjustment mode, the following graphics are shown.

The graphic will appear as in Figure 18 when the toggle sets the servo valve driver at neutral current (valve approximately centered at 0ma):

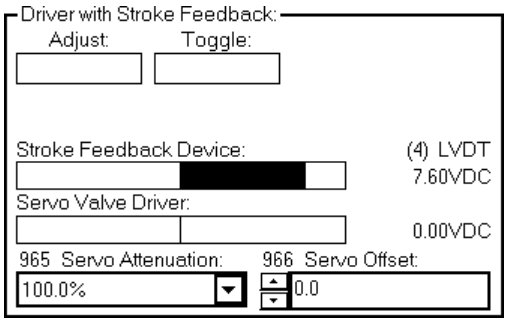

Figure 18: Neutral Current

The graphic will appear as in Figure 19 when the toggle sets the servo valve driver at maximum positive current:

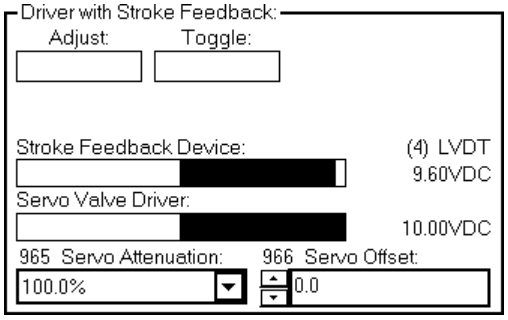

Figure 19: Positive Current

Finally, graphic will appear as in Figure 20 when the toggle sets the servo valve driver at maximum negative current:

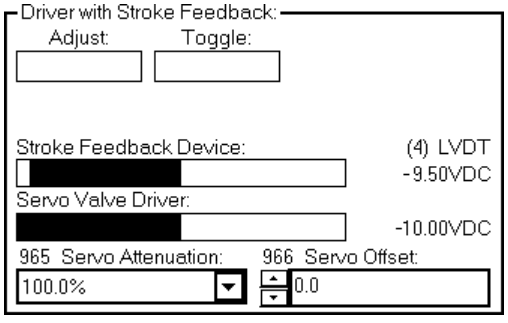

Figure 20: Negative Current

4.4.5 LVDT Adjustment Algorithm

Both the HP Limiter and Stroke Controller portions of the Pump Controller module rely on the LVDT being configured correctly. Typically, there are three (4) configuration parameters for each LVDT (Refer to Section 4.4.2 for a complete overview):

- Polarity
- Offset
- Course Gain
- Fine Gain

The general sequence of operations for LVDT scaling is to

- Set LVDT polarity to normal.
- Place the EPC in Adjust mode.
- Alternately Adjust the LVDT Offset and Gains until configured.
- Return EPC to normal operation mode.

4.4.5.1. Determining LVDT Configuration Range

The LVDT input should be scaled to match the range of stroke command. The range of stroke command is a factor of whether the pump is designed for uni- or bi-directional flow.

Servo valves are commanded with current: a positive current command will move the valve in one direction while a negative current command will move the valve in the opposite direction. A neutral (zero) current command will remove command to the valve: the valve might stay in its current state, or it may move in either direction.

For a **uni-directional** pump, only one port is available and the stroke can supply 0 to 100% of the rated flow. The LVDT should be configured so that the maximum positive toggle command will produce the equivalent of a +10VDC command for the LVDT input. The maximum negative toggle command should produce the equivalent of a 0 VDC command at the LVDT input. The range of 0 to +10VDC corresponds to DAC values of 2048 to 4095, or a percentage of 0 to +100% (refer to Section 5.1 for a discussion of the Diagnostic Representation of Numbers).

For a uni-directional pump, the midpoint command is +5VDC (DAC value of 3072 or +50% stroke).

For a **bi-directional** pump, two ports are available and the stroke can supply 0 to 100% of rated flow in each direction. Like the uni-directional valve, the LVDT should be configured so that the maximum positive toggle command will produce the equivalent of a +10VDC command for the LVDT input. The maximum negative toggle command, however, should produce the equivalent of a -10VDC command for the LVDT input. The range of -10VDC to +10VDC corresponds to DAC values of 0 to 4095, or a percentage of -100% to +100% (refer to Section 5.1 for a discussion of the Diagnostic Representation of Numbers).

For a bi-directional pump, the midpoint command is 0VDC (DAC value of 2048 or 0% stroke).

4.4.5.2 Adjustment Algorithm

The following algorithm may be used to optimally configure the unit. The PC Interface includes a Microsoft Excel ™ template (EPCConfig.xlt) that can be used to optimize the setup. The Excel template is also available through e-mail by request to oasys.support@oilgear.com.

1. Place the module in Adjustment mode (refer to Section 4.6.1.1).
2. Use an Initial setting of Offset = 512, Course Gain = 0, and Fine Gain = 0.
3. Toggle the Pump Command and note the LVDT readings at the maximum positive and negative toggle commands (refer to Section 4.4.4.3 regarding toggle command).
4. Determine the midpoint of these two LVDT readings and compare with the desired midpoint reading (see previous Section).
5. Adjust the LVDT offset so that the two LVDT readings have the desired midpoint reading.
6. Adjust the LVDT course gain upwards from the initial setting such that the positive and negative toggle commands produce LVDT signals as large as possible without either toggle command producing an LVDT signal out of the LVDT configuration range..
7. Repeat steps 3 through 6 until a one-digit course gain change is unable to produce LVDT signals within the configuration range. For a uni-directional pump, a positive toggle command should produce an LVDT signal slightly less than +10VDC and a negative toggle command should produce an LVDT signal slightly greater than 0VDC. For a bi-directional pump, a positive toggle command should produce an LVDT signal slightly less than +10VDC and a negative toggle command should produce an LVDT signal slightly greater than -10VDC.
8. Once the Course gain is found, adjust the fine gain upward from the initial setup. *Do not adjust the course gain and fine gain concurrently since the two do not function together in a straightforward linear fashion.*
9. Determine the midpoint of these two LVDT readings and compare with the desired midpoint reading (see previous Section).
10. Adjust the LVDT offset so that the two LVDT readings have the desired midpoint reading.
11. Adjust the LVDT fine gain downward from the initial setting until one of the two pump toggle commands is just under the pump range.
12. Repeat steps 9 through 11 until a one digit fine gain change produces LVDT signals spanning the entire configuration range. For a uni-directional pump, a positive toggle command should produce an LVDT signal of +10VDC and a negative toggle command should produce an LVDT signal of 0VDC. For a bi-directional pump, a positive toggle command should produce an LVDT signal of +10VDC and a negative toggle command should produce an LVDT signal of -10VDC.

Example 1: Balance an LVDT for a bi-directional pump (The example can be followed from the Example 1 sheet of the Excel template.)

Toggling with the initial values produces a low reading of -92.50% and a high reading of -40.60%. These readings should be offset to produce a low reading of -25.95% and a high reading of +25.95%. This is calculated by finding the midpoint of the current readings (-90.50 + -40.60)/2 = -66.55 and comparing that to the desired midpoint (a bi-directional pump should have a midpoint at 0). Adding 65.55 to each value results in -90.50 + 65.55 = -25.92 and -40.60 + 66.55 = 25.95. This setting is reached when the Balance is set to 411 (low and high readings of 25.90 and 26.20, respectively). Notice that at this point approximate values are good enough.

The user then attempts to adjust the gain to near saturation. At a Course gain = 30 the low reading is -91.60% while the high reading is -9.20%. The next gain (31) actually saturates the low reading to -100%, so 30 is used.

The user then attempts to offset the readings to low=-41.20% and high=+41.20%. The user finds this at Offset=334.

In a similar fashion, the user continues alternately selecting offset and course gain values. At step 6, a change in course gain saturates the low reading, so the user has successfully found the optimal setting for course gain. The user continues as before, but this time uses the fine gain to set the near saturation gains.

At step seven the user finds that a fine gain change from 5 to 6 saturates both readings. LVDT configuration is complete.

Example 2: Balance an LVDT for a unit-directional pump. The only difference between this and the previous example would be that the midpoint would be +50% rather than 0%. The user is invited to view the Example 2 sheet of the Excel template for this example.

4.5 Advanced Configuration

The Advanced Diagnostics Form contains the setups for Horsepower Limiting and Ramping functions.

4.5.1 Horsepower Limit Factor Calculation

The horsepower limit factor can be used to limit the power consumed by the hydraulic pump. To limit horsepower, the user first enters a value for the HP factor: this factor produces a PQ (pressure-flow) curve that defines a certain horsepower region (Figure 21). The user then sets the Pump Controller module with the proper settings for stroke and pressure feedback (see Section 4.3.2.3).

The horsepower limit factor can be determined in two ways: experimentally or theoretically.

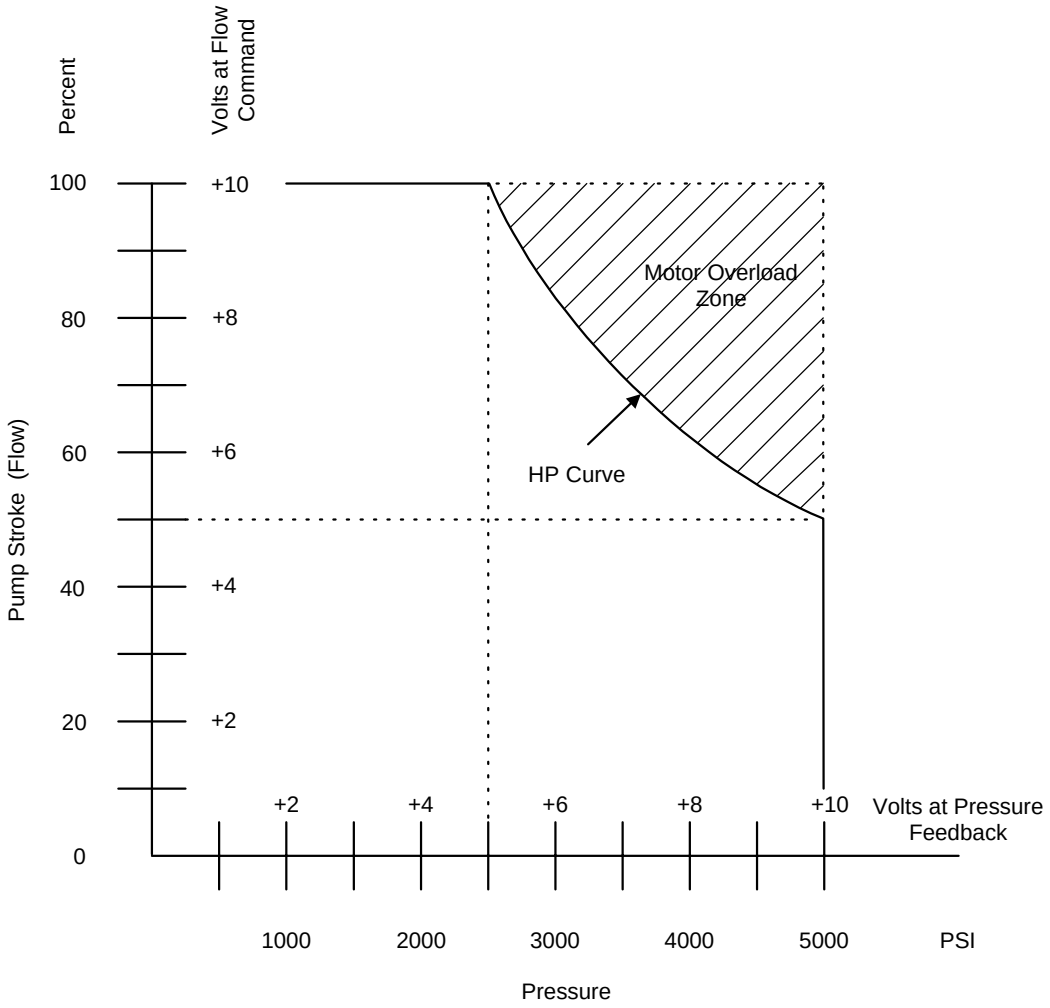

Figure 21: PQ (HP) Limit Curve

4.5.1.1 Experimental HP Limit Factor

For the Experimental HP Limit Factor, the user builds up pressure and increases stroke until the motor supplies the maximum rated current. This procedure requires a program that allows for direct stroke command, so a good function program to use would be the Simple Flow Program (refer to Section 4.2.6).

To determine the HP Limit Factor, the user must first configure the EPC for stroke feedback (Section 4.4.2) and connect a pressure transducer to an available analog input. An additional analog input can be used for stroke command.

The user then sets the HP factor to an initial setting of 100% and rigs the hydraulic circuit to build maximum pressure. Once this achieved, the user uses a current transducer and multimeter to measure motor current. Stroke to the pump is slowly increased, and the multimeter is monitored until the current to the motor is at the maximum rated current. At this point, the user notes the DAC reading for pressure and stroke.

The HP factor is determined by the formula:

$$HP_{factor} = \frac{(Q_{DAC} - 2048)(P_{DAC} - 2048)}{(2048)(2046)} \times 100\%$$

The PC interface allows a one-touch solution from the Advanced Configuration Form. The user simply presses the HP Experiment push-button once the maximum current is reached.

4.5.1.2 Theoretical HP Limit Factor

The HP limit factor can also be determined by the theoretical formulas. For metric units the horsepower factor is determined by the equation:

$$HP_{factor} = \frac{6.0 \times 10^7 \times Power}{D_{MAX} P_{XDCR} N} \times \eta$$

where

Power is the motor rating in kW

D_{MAX} is the maximum displacement of the Pump in ml/rev

P_{XDCR} is the maximum measured pressure in Bars
(i.e., the pressure corresponding to a 10VDC or 20mA reading)

N is the speed in rpm

and η is the pump efficiency

The user may also use conventional English units:

$$HP_{factor} = \frac{4.0 \times 10^7 \times Power}{D_{MAX} P_{XDCR} N} \times \eta$$

where

Power is the motor rating in horsepower

D_{MAX} is the maximum displacement of the Pump in in^3/rev

P_{XDCR} is the maximum measured pressure in PSI
(i.e., the pressure corresponding to a 10VDC or 20mA reading)

N is the speed in rpm

and η is the pump efficiency

Example 1: What HP factor would be used for a PVG075 powered by a 25 HP motor rotating at 1500 rpm. The EPC uses a 5000 PSI pressure transducer to measure pressure.

From Oilgear Bulletin 47019, a PVG075 has a maximum displacement of 4.60 in^3/rev and an overall efficiency of 80% at maximum pressure. These values are used in the formula:

$$HP_{factor} = \frac{4.0 \times 10^7 \times Power}{D_{MAX} P_{XDCR} N} \times \eta$$
$$= \frac{4.0 \times 10^7 \times 25}{(4.60)(5000)(1500)} \times 0.80$$
$$= 23$$

Example 2: What HP factor would be used for a PVG100 powered by a 50 kW motor rotating at 1500 rpm. The EPC uses a 400 Bar pressure transducer to measure pressure.

From Oilgear Bulletin 47019, a PVG100 has a maximum displacement of 98.3 ml/rev and an overall efficiency of 85% at maximum pressure. These values are used in the formula:

$$HP_{factor} = \frac{6.0 \times 10^7 \times Power}{D_{MAX} P_{XDCR} N} \times \eta$$
$$= \frac{6.0 \times 10^7 \times 50}{(98.3)(400)(1500)} \times 0.85$$
$$= 43$$

From the Advanced Configuration form, the user enters each of the variables in the desired system of units. Once this is done, the use presses the HP Theory command button to create a new value for the HP factor.

4.5.2 Ramp Configuration

The EPC module provides one ramp module and is configured by program items 870 through 874. The ramp can be configured from the Advanced Configuration Form (select Diagnostics and then Advanced).

Program Item	Range	Description
870	0 to 4	Ramp 1: Source
871	1 to 255	Ramp 1: Acceleration Rate
872	1 to 255	Ramp 1: Acceleration Step
873	1 to 255	Ramp 1: Deceleration Rate
874	1 to 255	Ramp 1: Deceleration Step

Table 17: Ramp Configuration

Source: The Source selects the Analog Input used as the ramp input. Valid entries are (0) No Ramp, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, or (4) LVDT (Analog Input 4). If No Ramp is selected, the ramp module will be disabled and the ramp function will be equal to 2048 DAC counts.

Rate and Step: The Ramp module provides different ramping rates for acceleration and deceleration. *Acceleration* is defined as increasing stroke, while *Deceleration* is defined as decreasing stroke. Ramping from +5V to +10V is acceleration, while ramping from +10V to +5V is deceleration. Ramping from -5V to -10V is also acceleration, since -10V provides greater stroke than -5V. Conversely, ramping from -10V to -5V is deceleration.

Since the EPC is a digital controller, the ramp is actually a staircase-like signal. The **Rate** describes the time length of each step and is expressed in whole number multiples of the closed loop update rate. The **Step** describes the potential step at each interval and is expressed as DAC counts.

The closed loop response is 1600 Hz. The Ramp Rate can be expressed in Volts/second with the equation

$$\text{Ramp Rate (Volts/s)} = [\text{ Closed Loop Response }] \times 0.004884 \times \frac{Step}{Rate}$$

The larger the ramp rate or step is, the more course the ramp stair casing will be. The time length of each step can be computed from the Rate setting:

$$\text{Time Length (seconds)} = \frac{Rate}{[\text{ Closed Loop Response }]}$$

$$\text{Potential Step (Volts)} = Step \times 0.004884$$

The Potential Step can be computed from the Step setting:

Example 1: A Rate of 255 and a Step of 1 is used for a 1600 Hz module. The Ramp Rate in Volts/second is

Ramp Rate = 1600 x 0.004884 x (1 / 255) = 0.03064 Volts/second
so a 10 Volt step would ramp over a period of 326 seconds (5 minutes:26 seconds).

The setting of Rate = 255 and Step = 1 results in the slowest ramping rate.

Example 2: A Rate of 1 and a Step of 255 is used for a 1600 Hz module. The Ramp Rate in Volts/second is

Ramp Rate = 1600 x 0.004884 x (255 / 1) = 1993 Volts/second
so a 10 Volt step would ramp in only 5 milliseconds.

The setting of Rate = 1 and Step = 255 results in the quickest ramping rate.

A user should select a ramp rate that is close to a desired value, while not producing an undesirable step. Generally, the lower the values for rate and step, the smaller the step.

Example 3: Which of the following are the optimal settings for a 0.5 Volt/second ramp?

(a) Rate = 15, Step = 1

(b) Rate = 31, Step = 2

(c) Rate = 47, Step = 3

(d) Rate = 125, Step = 8

Assuming a 1600 Hz closed loop response, the settings for (a) result in:

Ramp Rate = 1600 x 0.004884 x (1 / 15) = 0.5210 Volts/second
or a 1 x 0.004884 = 5mV step every 15/1600 = 9 milliseconds.

Similarly, the settings for (b), (c), and (d) result in

(b) Ramp Rate = 0.5042 Volts/second (10mV step every 19 milliseconds)

(c) Ramp Rate = 0.4988 Volts/second (15mV step every 29 milliseconds)

(d) Ramp Rate = 0.5001 Volts/second (39mV step every 78 milliseconds)

The optimal setting depends on the ramp requirements and system dynamics. If time is not critical, the settings for (a) which have the smallest step size would be optimal. If time is critical and the system dynamics allow for a larger step size, the settings in (d) should be used since the ramping is closer to the desired value (0.5001 V/s rather than 0.5210 V/s).

Deductive reasoning can be used to find the rate and step values for a desired ramp.

Example 4: What settings would be used to produce a 5-second ramp for a 0 to 10 Volt step command?

A 10 Volt / 5 second = 2 Volt/second ramp is desired. Since both the Rate and Step have values from 1 to 255, an arbitrary value of 10 is chosen for the Step and the Rate value is calculated:

$$\text{Ramp Rate} = [\text{ Closed Loop Response }] \times 0.004884 \times \text{Step} / \text{Rate}$$

$$\text{Rate} = [\text{ Closed Loop Response }] \times 0.004884 \times \text{Step} / [\text{Ramp Rate}]$$

$$= 1600 \times 0.004884 \times (10 / 2) = 39$$

A step of 10 and rate of 39 make a 2.0037 Volt/second ramp (48 mV step every 24 milliseconds). Because 10/39 is approximately 1/4, we would expect a step of 1 and a rate of 4 to be close to the ramp rate, yet provide a smaller staircase. Accordingly, a step of 1 and a rate of 4 create a 1.95 Volt/second ramp, this time with a 5 mV step every 0.6 milliseconds.

PC Interface: The PC interface contains a worksheet for ramp values (Advanced Diagnostics Form). The user selects a desired ramp rate and one of five resolution factors. The worksheet calculation function will display the results of the most optimal settings.

5 Module Diagnostics

The EPC has diagnostics available through both the front of the EPC (LEDs and testpoint) and the PC interface. However, due to the extensive features of the controller, the PC interface is the recommended diagnostic tool.

5.1 Diagnostic Representation of Numbers

Throughout this manual, reference has been made to DAC counts, percentages, and voltages. DAC count representation is the basis for all other diagnostic representation, since all internal numbers are represented within the controller as DAC (Digital-to-Analog Converter) counts.

5.1.1 DAC Counts

Most Diagnostic numbers are stored as a 12-Bit number from 0 to 4095. For an input or output variable, 0 DAC counts is equivalent to -10VDC while 4095 DAC counts is equivalent to +10VDC. 2048 DAC counts represents the midpoint of -10VDC and +10VDC, or 0VDC.

5.1.2 Voltage and Percentages

The PC interface allows a great range of diagnostic options. For most diagnostic Forms, the user can select to view input and output values as voltages or percentages. This feature is particularly helpful in LVDT adjustment.

A comparison summary of the different number representation follows:

Volts:	-10V	-5V	0V	+5V	+10V
Percentage:	-100%	-50%	0%	+50%	+100%
DAC (decimal):	0000	1024	2048	3072	4095

5.2 Basic Diagnostics on Front Panel

On the front of the EPC are 3 bi-color LEDS. These indicate Run / Fault conditions, Valve Current and Feedback. In addition, there is a testpoint labelled Analog Output 1. See Figure 22 for the location of the LEDS and Testpoint.

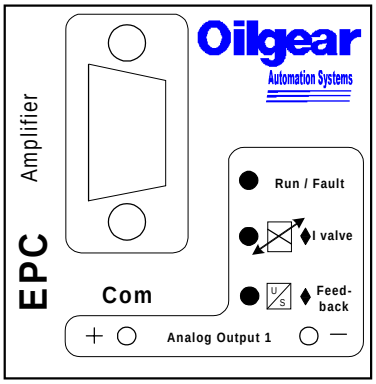

Figure 22: Front Label

5.2.1 Run / Fault LED

The bi-color LED provides diagnostics information about the Run / Fault conditions. The Run / Fault LED has several modes. See Table 22 for detail information on high priority faults and Table 23 for system messages.

Mode	Description
Steady Green	EPC has power (24V supply).
Flashing Green	EPC is communicating with a PC.
Steady Red	High priority faults.
Flashing Red	System messages and during power on for approximately 2 seconds.

Table 18: Run / Fault LED

5.2.2 Valve Current LED

The bi-color LED provides diagnostic information about the Valve Current. The color of Valve Current LED indicates the direction of the current to the valve. The intensity of the Valve Current LED indicates the amount of current to the valve.

Color	Direction	Intensity	Current
Green	Positive	Low	Low
Green	Positive	High	High
Amber	Negative	Low	Low
Amber	Negative	High	High

Table 19: Valve Current LED

5.2.3 Feedback LED

The bi-color LED provides diagnostic information about the Feedback. The color of the Feedback LED indicates the direction of the Feedback. The intensity of the Feedback LED indicates the amount of Feedback.

Color	Direction	Intensity	Feedback
Green	Positive	Low	Low
Green	Positive	High	High
Amber	Negative	Low	Low
Amber	Negative	High	High

Table 20: Feedback LED

5.2.4 Testpoint

A testpoint is accessible from the front of the EPC labeled Analog Output 1. It accepts 0.080" test probes. The testpoint is a programmable to 11 different selections. See Table 21 for selections.

5.3 Basic Diagnostics with PC Interface

The Basic Diagnostics are easily identifiable through the Analog IO Configuration Form. Items include Digital Input, Digital Output, Analog Input 1, Analog Input 2, Analog Input 3, LVDT (Analog Input 4), Programmable Outputs and Servo Driver Output. See Figure 23 for details. In addition, diagnostic values are available throughout as needed.

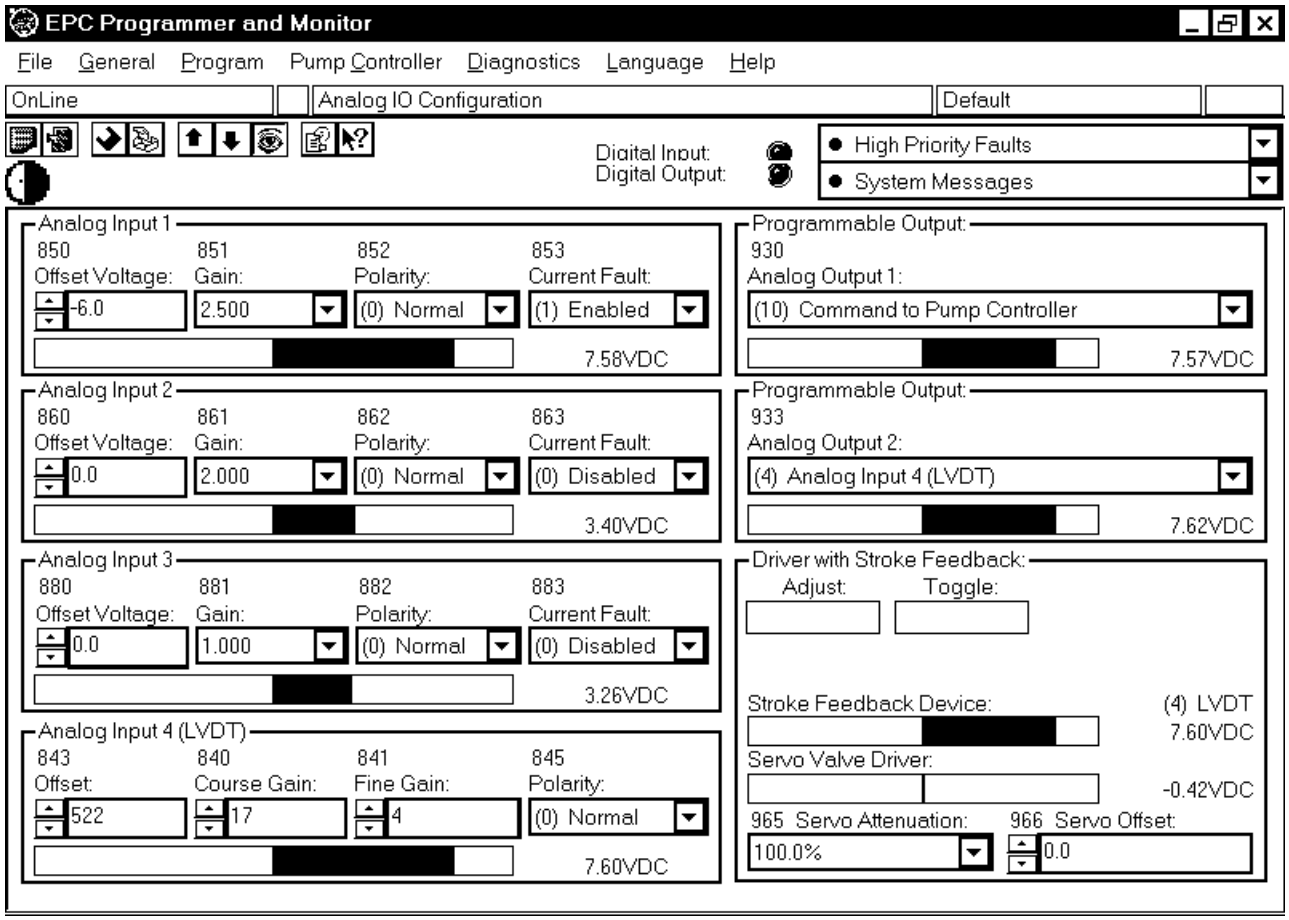

Figure: 23: Analog IO Configuration Form

5.4 Programmable Outputs Diagnostic

There are 2 programmable outputs. Analog Output 1 (program item 930) is located on the front of the EPC typically used as a test point for debugging. Analog Output 2 (program item 933) is located on terminals 7 and 8 typically connected to an analog input of a PLC.

The test point can easily be monitored externally. The signals for the programmable outputs are selected in the Analog IO Configuration Form. Available Diagnostic signals are shown in Table 21.

Selection	Diagnostic
0	Output Disabled
1	Analog Input 1
2	Analog Input 2
3	Analog Input 3
4	Analog Input 4 (LVDT)
5	Current Feedback Signal
6	LVDT sine wave excitation signal
7	+12VDC Supply
8	-12VDC Supply
9	Servo Driver Output
10	Command to Pump Controller (Output of Active Function Program)
11	Ramp

Table 21: Diagnostic Signals

5.5 Advanced Diagnostics

Advanced Diagnostics are viewable in the upper right hand corner of all Forms listed as High Priority Faults and System Messages. See Figure 23.

5.5.1 Module Faults

Module Faults are high priority faults that show EPC failure.

There are up to 8 (eight) module faults. Any fault will cause the PC interface to register a module fault. The eight faults are represented by a fault bit number from 0 to 7. A fault condition will be represented by the high priority box turning red. In addition, a triangle with an exclamation sign inside it indicates the specific fault.

Fault Bit	Fault Condition
0	Spare Fault Condition
1	Spare Fault Condition
2	Spare Fault Condition
3	Spare Fault Condition
4	LVDT Excitation Signal Fault
5	-12VDC Supply Fault
6	+12VDC Supply Fault
7	Non-Volatile Memory (EEPROM) Fault

Table 22: Fault Condition Codes

5.5.2 System Messages

System Messages display system messages about the EPC.

There are up to 8 (eight) module system messages. Any message will cause the PC interface to register a module system message. The eight faults are represented by a fault bit number from 0 to 7. A fault condition will be represented by the system message box turning red. In addition, a triangle with an exclamation sign inside it indicates the specific fault.

Fault Bit	Fault Condition
0	Line Break Warning - Analog Input 1
1	Line Break Warning - Analog Input 2
2	Digital Output Error
3	Line Break Warning - Analog Input 3
4	Spare Run-Time Message
5	Driver Current Fault
6	Module Closed Loop Warning
7	Module LVDT Adjustment Mode

Table 23: System Messages

Generally, a module message does not describe a module failure, but communicates that the EPC is probably configured incorrectly or a temporary fault condition exists.

For instance, the module can be configured to display a system message when the General Purpose Analog Input is less than 3mA (refer to Section 4.4.1). This condition would result in a run-time fault being generated. The most probably cause of the Digital Output Error is to incorrectly connect the output as a digital input.

6 Technical Data

6.1 Module Pinout

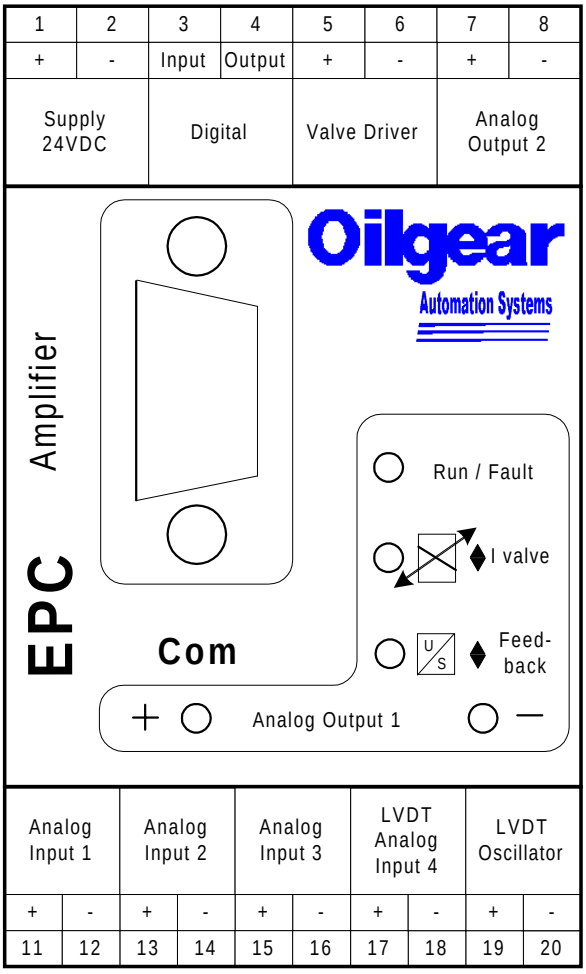

Figure 24: Module Pinout

6.2 Sample Connection Diagram

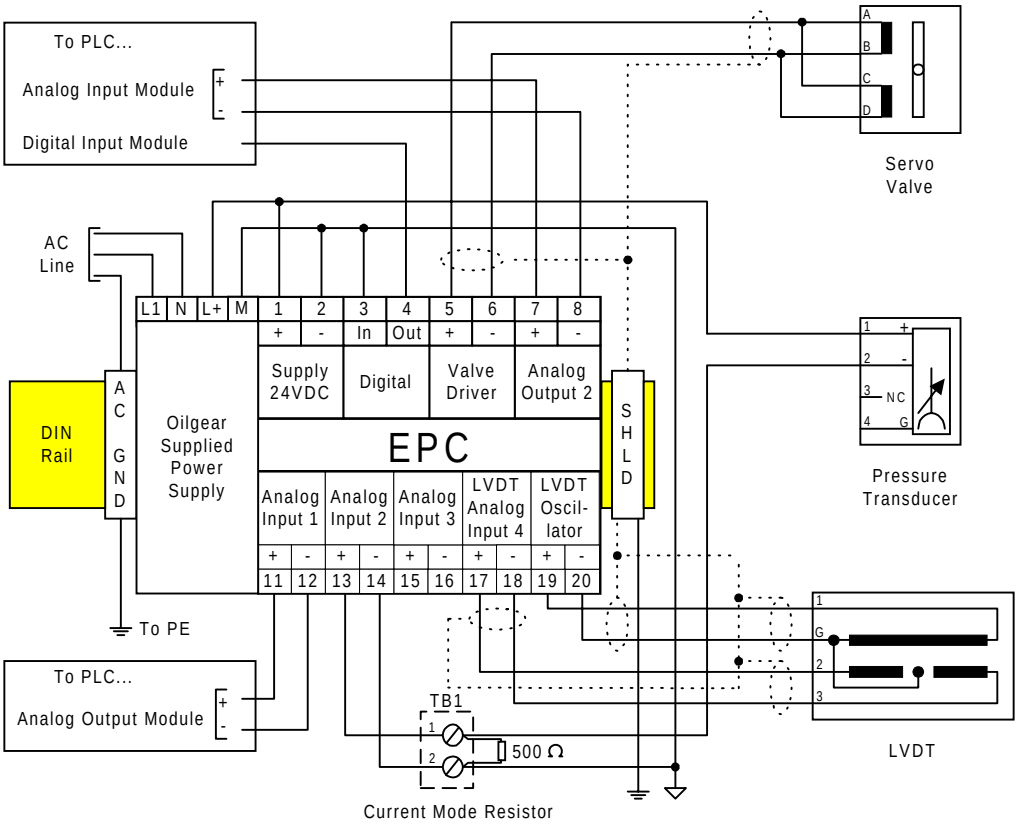

Figure 25: Sample Connection

The Sample Connection shows a typical configuration in which the user is using Function Program 3 (Flow with Pressure Limit) as the only configured program.

The user uses a PLC output (-10VDC to 10VDC) as the command to the EPC at Analog Input 1. The digital input is tied to common, since the user does not need dynamic function selection. A 4-to-20mA transducer is used as a pressure feedback command and is attached to Analog Input 2. A 500Ω resister is placed across Analog Input 2 for current mode. A single LVDT is used for stroke feedback, while pins 7 and 8 are used to return the LVDT feedback signal to the PLC. The digital output is also returned to the PLC and is used to monitor fault conditions (the EPC is running in mode 0; refer to Section 4.1.2.1).

6.3 Specifications

Supply Voltage:	+24VDC (18VDC to 36VDC)
Supply Current (Run):	100mA + Maximum Driver Current
Supply Current (Start-Up):	1200mA
Maximum Driver Output:	+/- 250 mA (Linear) +/- 1000 mA (PWM)
Closed Loop Update Rate:	1600 Hz
Size:	45mm wide × 75mm height × 105mm length 1.77in. wide × 2.95in. height × 4.13in. length (4.53in. length with connector)
Ambient Temperature:	0 °C to +70 °C
Mounting:	DIN EN 50022-35

6.4 IO Summary

Digital Input:	1	Digital High = 5VDC to 36VDC
Digital Output:	1	Vsupply (short circuit protected)
Analog Inputs (General Purpose):	3	Voltage (Potential) mode: +/- 10VDC Current mode: 0 to 20mA or 4 to 20mA (see Note 3)
LVDT Inputs:	1	Approximately 0 to 20VDC
Test Point Output	1	+/- 10VDC (see Note 1)
Programmable Outputs	2	+/- 10VDC (see Notes 1, 2)

Notes:
1. Output signal programmable (refer to Section 5.3)
2. Includes testpoint.
3. A 500Ω resister is required across the analog input to convert the current into voltage. See Figure 20 for a typical connection for current mode on Analog Input 2.

6.5 Cable Recommendations and Terminal Information

Cable recommendations and terminal information are as follows (equivalent cable may be substituted).

EPC	Connection	Cable Type	Gauge	Belden P/N	Length (max)
Linear	Torque Motor	2 Conductor Shielded	#22 AWG	8761	250 Feet
Linear	LVDT	4 Conductor Shielded	#24 AWG	9729	250 Feet
PWM	Valve	2 Conductor Shielded	#18 AWG	8760	250 Feet
PWM	LVDT	4 Conductor Shielded	#24 AWG	9729	250 Feet

Table 24: Cable Recommendations

Terminal Numbers	Hole Diameter	Gauge
1 - 8	1.3 mm	14 - 26 AWG
11 - 20	1.1 mm	16 - 26 AWG

Table 25: Terminal Information

7 Technical Support

For US customer support, contact the Oilgear Automation Systems Division of the Oilgear Company:

Oilgear Automation Systems (OAsys)
The Oilgear Company
2300 So. 51st. Street
PO Box 343924
Milwaukee, WI USA 53234-3924
(Shipping Address Zip Code is 53219-2340)

Voice Support:	414-327-1700
Fax Support:	414-327-0532
E-Mail Support:	oasys.support@oilgear.com
Website:	www.oilgearsystems.com

For European Technical Support, contact the Electronics Division of Oilgear Towler GmbH:

Oilgear Towler GmbH
Im Gotthelf 8
D-65795 Hattersheim
(Industriegebiet Eddersheim)
DEUT (Germany)

Voice Support:	(+49) 6145 377 0
Fax Support:	(+49) 6145 30770
E-Mail Support:	OTG_electronic@compuserve.com

8 Ordering Information

EPC Modules are available in three standard options: **Non-Configured Modules, Standard Configured Modules,** and **Small Engineered System Units.**

Non-Configured Modules are intended for customer-engineered systems and OEM applications. It is expected that the user has completed Oilgear training or has significant experience with hydraulic systems and Oilgear electronics. Wiring diagrams and installation drawings are not provided beyond the standard bulletin and/or PC Interface Software online help (both items ordered separately). All accessory items should be ordered as separate line items (please see the Accessories Section for more information).

Standard Configured Modules are intended for standard single-unit applications or replacement parts for Small Engineered Systems. The modules are pre-programmed by Oilgear prior to shipping, but may require some field adjustment. Wiring diagrams and installation drawings are not provided beyond the standard bulletin and/or PC Interface Software online help (both items ordered separately). All accessory items should be ordered as separate line items (please see the Accessories Section for more information).

Small Engineered System Units are fully engineered and tested application system components including customized wiring diagrams and installation drawings. The number of EPC modules determines the base price of the Small Engineered System. In addition to wiring and installation drawings, Oilgear provides Configured Modules to simplify replacement parts. All accessory items should be ordered as separate line items (please see the Accessories Section for more information).

EPC Modules:

Oilgear Part No.	Description
L723888-110	PWM, Moog 20L, VM Control, Max to +/-800mA, 17KHZ
L723888-111	PWM, Moog 40L, VM Control, Max to +/-800mA, 7KHZ
L723888-112	PWM, P2C, Proportional Solenoid, Max to +600mA, 17KHZ
L723888-114	PWM, VSC4/SCVA/SCVP Valves, Max to +/-250mA, V-S/V-V/V-W
L723888-9XX	Special or System Applications

Table 26: EPC Modules

Accessories:

PC Interface Support:

Oilgear Part No.	Description
250858-004	PC Interface Software (Windows 95, 98, 2000, NT 4.0, ME) CD ROM (Floppy Disk Images can be copied from CD)
247909-494	Serial Communications Cable for PC Interface Software and 1XX EPC Null Modem Cable 3 Meters in Length (DB9 Female to DB9 Female)

Table 27: PC Interface Support

DIN Rail Mount Power Supplies (DC 24 V Output/AC 120-230 V Input):

Oilgear Part No.	Description
243432-114	24V DC/1.3A DIN Rail Mount Power Supply
243432-115	24V DC/2.5A DIN Rail Mount Power Supply
243432-117	24V DC/5.0A DIN Rail Mount Power Supply
243432-118	24V DC/10.0A DIN Rail Mount Power Supply

Table 28: 24V DC Power Supplies

DIN Rail Mount Power Supply (DC 12 V Output/AC 120-230 V Input):

Oilgear Part No.	Description
243432-129	12V DC/1.25A DIN Rail Mount Power Supply

Table 29: 12V DC Power Supply

DIN Rail Mount Power Supply (DC 24 V Output/DC 10-30 V Input):

Oilgear Part No.	Description
Consult Factory	

Table 30: 24V DC Power Supply

Mounting Kits:

Oilgear Part No.	Description
K724094-001	**Kit 1, For (1) EPC and (1) 1.3A Power Supply Includes:** (8”) DIN Rail, (2) End Stops, (1) Spacer and (1) Ground Terminal
K724094-002	**Kit 2, For (2) EPCs and (1) 2.5A Power Supply Includes:** (13”) DIN Rail, (2) End Stops, (2) Spacers and (2) Ground Terminals
K724094-003	**Kit 3, For (3) EPCs and (1) 5.0A Power Supply Includes:** (14”) DIN Rail, (2) End Stops, (3) Spacers and (3) Ground Terminals
K724094-004	**Kit 4, For (4) EPCs and (1) 10.0A Power Supply Includes:** (17”) DIN Rail, (2) End Stops, (4) Spacers and (4) Ground Terminals
K724094-005	**Kit 5, For (5) EPCs and (1) 10.0A Power Supply Includes:** (21”) DIN Rail, (2) End Stops, (5) Spacers and (5) Ground Terminals
K724094-006	**Kit 6, For (6) EPCs and (1) 10.0A Power Supply Includes:** (24”) DIN Rail, (2) End Stops, (6) Spacers and (6) Ground Terminals

Table 31: Mounting Kits

DIN Rail:

Oilgear Part No.	Description
250629-001	DIN EN 50022-35 Rail (inch)

Table 32: DIN Rail

Enclosures:

Oilgear Part No.	Description
Consult Factory	

Table 33: Enclosures

Pressure Transducers, Resister and Snubbers:

Oilgear Part No.	Description
L251287-753	5000 PSI 4-to-20mA Output 1/4 NPT
L251287-853	5000 PSI 4-to-20mA Output #4SAE
403895-568	500 Ohm Resister for 4-to-20mA Transducers (499 Ohm 1%)
248172-001	Snubber NPT
248172-004	Snubber SAE

Table 34: Pressure Transducers, Resister and Snubbers

Oil-Tight Preset Units

Oilgear Part No.	Description
245478-003	Single Potentiometer 5K Ohm Single Turn (Model #SD304-00x)
L406132-00x	Single Potentiometer 10-Turn with Digital Counter (Model #SD305-00x)

Table 35: Oil-Tight Preset Units

NOTES:

1. Order Accessories as separate line items.

2. PC Software and Interface Cable IS REQUIRED for 1XX Series EPC modules.

3. Electronic version of manual (Adobe™ PDF) is included at no charge with PC Interface software or by request at oasys.support@oilgear.com. PC interface software includes shareware version of Adobe Acrobat Reader ™.

4. Maximum Number of EPC Modules for each Power Supply:
(Calculated using 1.25A in-rush/900mA operating current for EPC PWM).

	243432-114 1.3A Supply	243432-115 2.5A Supply	243432-117 5.0A Supply	243432-118 10.0A Supply
EPC	1	2	4	8

Table 36: EPCs Per Power Supply

5. Mounting Kits includes DIN rail, end stops, and ground terminals for proper mounting of EPC(s) with power supply.

6. Technical documentation is available online at www.oilgearsystems.com.

9 Appendix

9.1 Appendix A Generation 1 Control

Generation 1 Control for Flow with Pressure Limit is included with EPC modules with software versions V1.06 or earlier. These programs work well for some hydraulic, but can become unstable if used in stand-alone control applications with high fixed flow commands.

The PQ algorithms work optimally when the flow command is monitored and decreased as the pressure feedback signal increases. An external controller (such as a PC or PLC) should be used to monitor the pressure feedback signal and decrease the flow command signal.

Better stability can be achieved in stand-alone control situations by setting the KI term to zero (0) and using the Pressure Limit Preset and/or the Pressure Limit Source to specify a Pressure Breakpoint Signal (i.e., a pressure at which the flow command begins to become limited). The KP term is then adjusted so that at the desired pressure limit, the output signal of the program is neutral stroke (or a stroke needed to maintain the pressure limit). This is, in fact, the only way to configure the Generation 2 Flow with Pressure Limit Program.

Any Generation 1 EPC module can be upgraded to Generation 2 software. Please refer to Technical Support in section 7.

9.1.1 Flow with Pressure Limit Programs (42x, 43x)

Program Item	Range	Description
420	0 to 100	Program 3: Flow Command Preset
421	1 to 100	Program 3: Pressure Limit Preset
422	0 to 5	Program 3: Flow Command Source
423	0 to 5	Program 3: Pressure Limit Source
424	1 to 5	Program 3: Pressure Feedback Source
425	0 to 1	Program 3: Program Output Destination
426	0 to 100	Program 3: KP
427	0 to 100	Program 3: KI
430	0 to 100	Program 4: Flow Command Preset
431	1 to 100	Program 4: Pressure Limit Preset
432	0 to 5	Program 4: Flow Command Source
433	0 to 5	Program 4: Pressure Limit Source
434	1 to 5	Program 4: Pressure Feedback Source
435	0 to 1	Program 4: Program Output Destination
436	0 to 100	Program 4: KP
437	0 to 100	Program 4: KI

Table 37: Flow with Pressure Limit Programs

Function Programs 3 and 4 provide for Flow with Pressure Limit Control. Program 3 is configured in program items 420 through 429 in the Program 3 Form. Program 4 is configured in program items 430 through 439 in the Program 4 Form.

Flow Command Preset: The Flow Command Preset allows for direct numeric input for the control program. The preset is configured as a percentage, with 0% being equivalent to a 0VDC input signal and 100% being equivalent to a +10VDC signal.

Pressure Limit Preset: The Pressure Limit Preset allows for direct numeric input for the control program. The preset is configured as a percentage, with 0% being equivalent to a 0VDC input signal and 100% being equivalent to a +10VDC signal.

Flow Command Source: The Flow Command Source selects the source of the flow command for the program. Valid entries are (0) Preset Value, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3), (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If the Preset Value is chosen, the Flow Command Preset is used as the flow command.

Pressure Limit Source: The Pressure Limit Source selects the source of the pressure limit command for the program. Valid entries are (0) Preset Value, (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1. If the Preset Value is chosen, the Pressure Limit Preset is used as the pressure limit command.

Pressure Feedback Source: The Pressure Feedback Source selects the source of the pressure feedback for the program. Valid entries are (1) Analog Input 1, (2) Analog Input 2, (3) Analog Input 3, (4) LVDT 1 (Analog Input 4), or (5) Ramp 1.

Program Output Destination: The Program Output Destination selects the output of the program. Valid entries are (0) Pump Controller or (1) Direct. If the Pump Controller is chosen, the output of the Program will be the input to the Pump Controller module. If Direct is chosen, the output of the Program will by-pass the Pump Controller module and is passed directly to the servo driver. Under most circumstances, the Pump Controller should be chosen as the output destination.

KP and **KI**: KP and KI provide the proportional and integral constants, respectively, for the PI control algorithm. Both terms are expressed as 0 to 100% of a maximum value. The PI control loop can be made a P-only control loop by setting the KI term to 0. Likewise, the PI control loop can be made an I-only control loop by setting the KP term to 0.

Program Overview: The Flow with Pressure Limit Control Program is a flow limit algorithm; the PI Control algorithm is only used if the pressure feedback is greater than the pressure limit. Comparing the command to the feedback value produces an error value. The error is multiplied by the KP and KI constants to produce type Yp and Yi contributions to the pressure limit signal. This signal, in turn, is used to limit the flow command to the program output. If the pressure limit command is greater than the feedback signal, no pressure limit command will be added to the Flow command; the flow command will be transposed directly through to the program output.

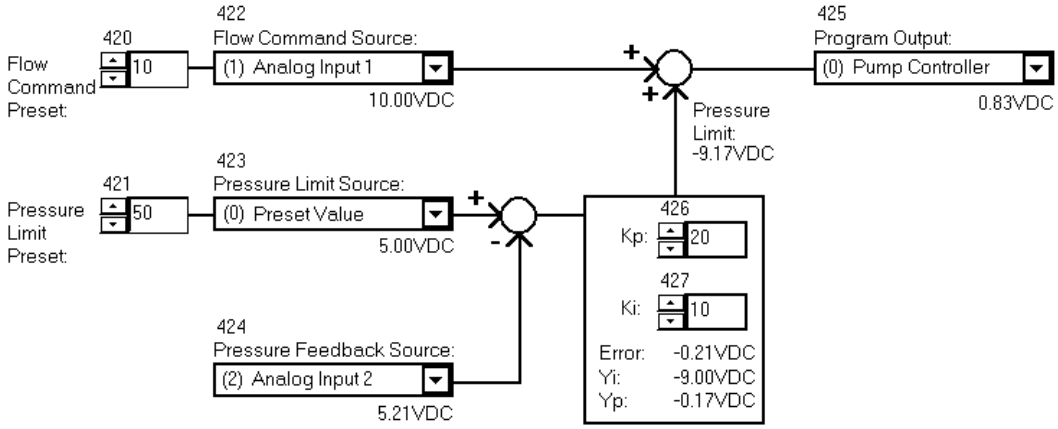

Figure 26: Flow with Pressure Limit Program

Example: Figure 26 shows Program 3 Form for Flow with Pressure Limit (Generation 1). The Flow Command Source is Analog Input 1 (program item 422=1). The Flow Command Preset is set to 10% (program item 420=10) although the Flow Command Preset is not used in this example.

The Pressure Limit Command Source is the Preset Value (program item 423=0), therefore the pressure limit command is set at a 50% level (program item 421=50). The Pressure Feedback Source is Analog Input 2 (program item 424=2).

The error signal is produced by comparing the Pressure Limit Source to the Feedback signals: 5.00V - 5.21V = -0.21V. The Yi and Yp signals are produced from the PI controller and the Pressure Limit value is roughly equal to their sum: -9.00V + -0.17V = -9.17V.

The Pressure Limit Value is used to decrease the flow command: 10V- 9.17V = 0.83V. Finally, the Program Output is set to the Pump Controller (program item 425=0).

9.1.2 Advanced Flow with Pressure Limit Programs (48x, 49x)

Currently, the Advanced Flow with Pressure Limit Programs are identical to the previously mentioned Flow with Pressure Limit Programs (refer to Section 9.1.1).